Concept of Operations

(ConOps)

Checkout and Launch Control System (CLCS)

84K00220

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NOTE: See “**Supporting Document Note**” on following page

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Supporting Document Note: CLCS Acronyms and Definitions of many common CLCS terms may be found in the following documents:

CLCS Acronyms	84K00240
CLCS Project Glossary	84K00250

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CONCEPT OF OPERATIONS

CHECKOUT AND LAUNCH CONTROL SYSTEM (CLCS)

1. INTRODUCTION

The Checkout and Launch Control System (CLCS) is the ground-based computer system used to checkout and launch the Space Shuttle at Kennedy Space Center (KSC), Florida.

The CLCS replaces the 1970s-vintage Launch Processing System (LPS) with the new system which is based on a mix of state-of-the-art Commercial Off The Shelf (COTS) technology and developed software to tailor the CLCS to perform the tasks unique to checking out and launch of large space transportation and space station systems. CLCS is based on open hardware and software standards, easily incorporates new technology and user-developed applications, and provides user interface improvements and lower life-cycle costs than the LPS. COTS software is utilized instead of developing custom software everywhere that CLCS requirements can be safely satisfied by these products. All custom software is written in industry-standard high-level languages which have demonstrated a high degree of portability between platforms. COTS hardware is also utilized where possible to provide a reliable system that is modular, expandable, and extensible.

CLCS is composed of the Real Time Processing System (RTPS), Shuttle Data Center (SDC), Simulation System (SIM), and the Business And Support Information Service (BASIS).

The RTPS provides the capability to monitor and control the elements of the Space Shuttle flight vehicle and Ground Support Equipment (GSE). The SDC records and archives test data, hosts various data bases, and provides the capability to build test packages for configuration of the RTPS. The capability to debug and certify RTPS software and to aid in the training of test personnel is provided by the Simulation System. The BASIS provides connectivity and access from support workstations to non-RTPS applications and data resident on various business systems.

CLCS provides support for the Space Shuttle Program into the 21st Century and a basic infrastructure upon which to base future design projects such as the orbiter upgrades and the Reusable Launch Vehicle (RLV).

1.1 SCOPE

This CLCS Concept of Operations (ConOps) defines the user community's operational concepts for the CLCS. These high-level requirements form the basis of functional requirements contained in the CLCS System Level Specification (SLS), and the detailed design contained in the CLCS System Design Document (SDD). The ConOps document specifically relates to the replacement of LPS with CLCS and does not address operational interfaces for future projects and new initiatives. However, it is intended that CLCS will be developed and deployed in a flexible, adaptable, and portable manner so as to accommodate such future initiatives. Documents detailing CLCS operations for these upgrade projects will be produced as required.

1.2 CLCS OPERATIONAL OVERVIEW

Space Shuttle processing at KSC can be generally categorized in 4 ways: 1) non-integrated flight element and GSE processing; 2) integrated vehicle processing, including launch, 3) local operations which occur at the processing site, and

4) flight element processing at specialized processing sites. Figure 1-1 illustrates the wide distribution of CLCS data required across the center and the agency to support processing activities.

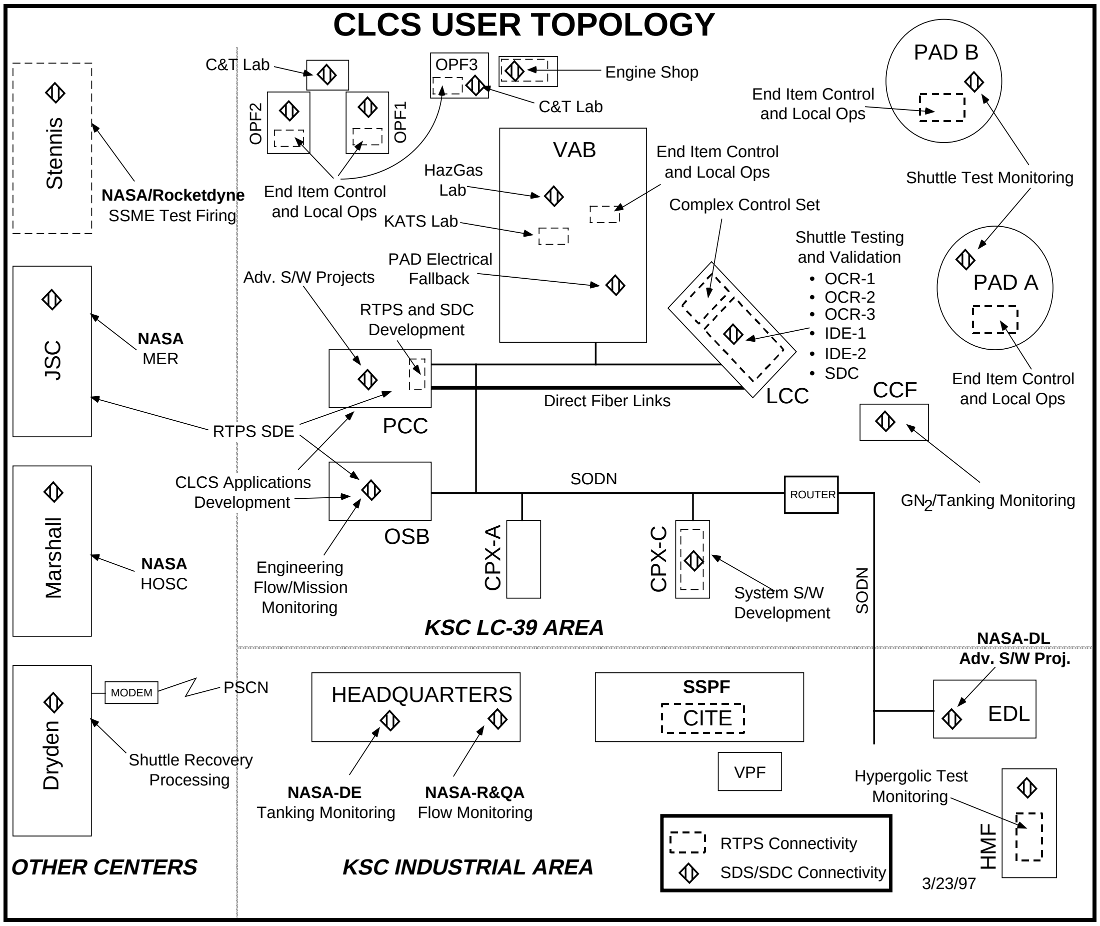

Figure 1-1 CLCS User Topology

Both integrated and non integrated processing is supported from three Operations Control Rooms (OCR) located in the Launch Control Center (LCC). Each OCR is configurable as required to support either integrated or non-integrated flight elements and GSE testing. Two of the OCRs support both categories of testing, while the third is designed and built to support only non-integrated testing. All OCRs may be divided into multiple “Test Sets” by associating series of gateway groups and control groups with various processing facilities. This capability permits multiple vehicles with associated GSE and facility systems to be processed out of the same control room. Testing may be occurring in all three control rooms on the same day with a mixture of flight elements, GSE, and facilities.

While more than one non-integrated vehicle can be tested simultaneously out of the same control room, it is operational policy to process only the integrated vehicle, associated GSE, and the VAB/pad systems supporting that vehicle out of a single OCR. Integrated vehicle testing is defined as the period when the orbiter is mated to its External Tank and Solid Rocket Boosters in the VAB through launch. During the checkout and launch of the integrated vehicle on the pad, data is made available for review and analysis at other NASA Centers, including: the Huntsville Operations Support Center (HOSC) at Marshall Space Flight Center (MSFC); the Mission Evaluation Room (MER) at Johnson Space Center (JSC); and other centers as required by inter-center agreements.

In support of non-integrated and integrated testing from the OCR's, a capability to perform local testing of vehicle systems and GSE at selected operational sites is also provided by CLCS. Local operations allow the engineer on the floor at the processing facility to directly monitor and command operations and perform troubleshooting. CLCS local operations are not satellite control rooms, the purpose is to carry the test to the vehicle which eliminates the need to have an engineer supporting the task from the OCR. The modes supported include local equipment used in a standalone mode, local equipment connected to an OCR, or a plug-in portable workstation attached to the command and control system.

At the same time that processing is occurring in the OCRs, processing activities on subsystem flight elements occurs at off-line specialized processing sites. Specifically, checkout of the Orbiter Maneuvering and Reaction Control Subsystems at the Hypergolic Maintenance Facility (HMF) in the KSC Industrial Area, main engines at the Space Shuttle Main Engine Processing Facility (SSMEPF), Shuttle avionics validation at the Kennedy Avionics Test Set (KATS) and the Shuttle Avionics Integration Laboratory (SAIL) at the Johnson Space Center, and payloads at the Cargo Integration Test Equipment (CITE) in the Space Station Processing Facility (SSPF) could be occurring. In addition, Dryden Flight Research Center (DFRC) has the capability to utilize the CLCS Shuttle Data Stream (CLCS SDS) for post-landing processing when the orbiter lands there.

While it is not technically a specialized processing site, the Central Operations Facility (COF) is a concept that brings together varying operations and maintenance functions to a centralized location. Systems in the Complex 39 area (e.g. RTPS, SDC, Simulation, CCS, etc.) will locate their twenty-four-hour-a-day operations and "network centric" functions in the COF. This centralization concept enables CLCS and other Complex 39 systems to take advantage of similarities of functions and expertise by forming a shared pool of experts and analysts capable of serving multiple systems.

It is important to note that the Complex Control Set (CCS) which provides control of facility systems such as HVAC, pneumatic, power, and water and waste is currently undertaking a study to determine if it will be replaced by a commercial utility control system or a derivative of CLCS. The preliminary results from this study, which indicate a preference for a commercial utility control system, are represented in this document.

An essential aspect of Shuttle processing is Simulation. The CLCS Simulation System supports launch team training, subsystem training, system verification, checkout, and debug of developing software. Simulation is provided at the link level via the Video Simulation Interface (VSI), at the CLCS network level, and by way of a simulation server to the desktop environment for initial debug support.

In all categories of processing, support is required for data storage and distribution from SDC and the simulation system. The SDC includes various data recording and retrieval resources that provide access to near real-time and historical data including raw link level data and recorded network data. Various formatted and unformatted data retrievals are provided for both CLCS data and historical CDS/CCMS data. This includes services similar to those provided in LPS by HI-TRX, the Record and Playback System (RPS), and the Processed Data Recorder (PDR). In addition, SDC provides the CLCS SDS to the KSC office environment as well as local and remote operational areas. The CLCS Shuttle Data Stream (CLCS SDS) provides all measurement data processed by the RTPS. This includes:

- Shuttle Command and Measurement data
- GSE Measurement and Command data
- Derived Measurement data (i.e., Fused, Pseudo, and System FDs)
- Other data systems (e.g., HUMS, Metro, PMS, etc.)

Finally, in order to continue processing successfully, CLCS requires ongoing support, maintenance, and sustaining efforts. It is intended that a reduced level of support, maintenance, and sustaining activities will be necessary to keep CLCS operational. CLCS support activities include management, control, configuration, and recovery of CLCS system resources, and the preparation of System Configuration Identifiers (SCID) and Test Configuration Identifiers (TCID) in support of testing. CLCS maintenance activities include failure analysis, fault isolation, and preventative maintenance. Sustaining activities include updates for hardware, system software/SCIDs, application software, and data bank/TCID builds.

1.3 DOCUMENT OVERVIEW

The CLCS Concept of Operations document is organized into six sections. Section One contains the introduction of the operations concept and an operational overview of CLCS. Section Two contains definitions of CLCS physical characteristics and roles and responsibilities. Section Three is separated into two subsections, Support Infrastructure and Test Operations, which describe how CLCS will be used for all aspects of operations. The fourth section discusses sustaining processes, including hardware, system software, and application software along with test configuration activities. Section Five describes the environments necessary to support test operations in the control rooms and off-line processing sites. The last section contains operations scenarios describing integrated processing through launch, non-integrated multi-flow processing, and the simulation environments.

2. OPERATIONS CONCEPTS

This section discusses roles and responsibilities, the physical and functional characteristics of the LCC set, specialized processing sites, local operations, and the software development and sustaining environments.

2.1 ROLES AND RESPONSIBILITIES

To aid in understanding the operational requirements of CLCS, five separate categories of CLCS personnel are defined.

2.1.1 Users

Users are personnel who utilize CLCS resources to support and perform processing test operations. Users are divided into three groups defined by the types of tasks they perform.

The first task is test preparation. Users who support test preparation include test application developers, data base developers, and test configuration builders/managers. Preparation consists of those tasks which are required to prepare all aspects of test definition and configuration.

The second task is test execution. Users who perform test execution tasks include system engineers responsible for various vehicle and GSE systems, and test conductors. Execution consists of control and supervision of CLCS test operations.

Finally, users who perform support administration tasks include system administrators, system configuration managers, and system data base administrators. Administration consists of account maintenance, configuration management, and maintenance of system data bases.

2.1.2 Operators

Operators are defined as those persons who manage and monitor CLCS system resources in support of processing. The CLCS Test Conductor residing at the set master and test set master consoles are responsible for these activities. CLCS operations personnel perform all of the activities needed to prepare for the execution of any scheduled test, continually monitor the health and status of the test set during execution, make reconfigurations where needed, control work flow, and arrange for maintenance services as required.

2.1.3 Maintainers

Maintainers are defined as personnel who, at the organizational level, analyze, diagnose, repair, replace, revalidate, or calibrate CLCS subsystems or component of subsystems, or who otherwise make operational any CLCS equipment which was previously in a non-operational state. Additional maintainers provide support at the intermediate and depot level repair facilities.

2.1.4 Developers

Developers are responsible for the design and development of CLCS. The development process is outside the scope of this ConOps document. The developers follow best commercial practices in the development and documentation of CLCS. All processes and tools used in the development of CLCS, including hardware, software, processes, licenses, etc. will be turned over to the sustaining engineering group upon completion of the development cycle. It is anticipated the sustaining engineering group will continue to use the same processes and tools used during development.

2.1.5 Sustainers

Sustaining engineering begins when a product is turned over from the design agency (CLCS developers) to the end-user's sustaining activity.

Sustaining engineering provides the expertise to: update existing and write new system specifications; update existing and develop new procurement specifications for upgrades and new procurements; and design, develop, plan, coordinate, and implement upgrades to existing CLCS hardware and software. Hardware sustaining engineering also covers LPS-legacy equipment and maintains all interface control drawings for the CLCS and LPS-legacy equipment. Software sustaining engineering provides the expertise to maintain and develop CLCS system software and COTS operating systems and tools. This includes regression testing new releases of COTS software to ensure its compatibility with CLCS, and evaluating new COTS software for applicability to the CLCS mission.

Both sustaining engineering functions also provide troubleshooting expertise in support of the O&M community to assist in solving problems related to CLCS hardware and software.

2.2 LCC SET PHYSICAL CHARACTERISTICS

The Launch Control Center (LCC) located at Launch Complex 39 contains the primary CLCS areas needed to safely and efficiently process Space Shuttle vehicles. The LCC contains several CLCS sets, including the LCC Set, SDC, SIM, COF, and various development sets. The LCC set consists of three OCRs.

2.2.1 Operational Control Rooms

The CLCS equivalent to the CCMS firing rooms are known as Operational Control Rooms (OCR). These are capable of providing command, control, and monitoring of ground and vehicle processing for an entire flow, from landing to launch. Each OCR contains three distinct areas:

1. the "Front Room"
2. the Common Equipment Area (CEA)
3. the Shared Input/Output area

OCR-1 and OCR-2 are configured with sufficient resources to fully support integrated processing through launch. The third OCR contains sufficient assets to process a minimum of two non-integrated flows simultaneously, and is not designed to support major integrated tests or launch countdown.

2.2.1.1 OCR Front Room

The Front Rooms are equipped to efficiently facilitate all aspects of Shuttle processing. Each OCR is designated a sensitive area and is equipped with personnel access control and accountability system. The floors are protected with static-free carpet to reduce electro-static buildup and discharge, while the walls and ceilings have sound deadening material installed to reduce background noise. The room is divided into three distinct functional areas. The large main area is equipped with system engineering consoles and support modules for the engineers performing processing. There are several tiered levels that constitute the Test Director (TD) and Test Conductor (TC) area that are equipped with test conductor consoles and support modules. Finally, the enclosed areas known as the Operations Management Room (OMR) and Operations Support Room (OSR) permit management visibility of the launch team during operations and are equipped with support modules. Table 2-1 details the quantity of consoles, workstations, and other equipment located in each OCR.

	TC Consoles	Support Modules	SE Consoles	Safing Panels	Command and Control Workstations	Support Workstations
OCR-1	18	20	36	36	38	72
OCR-2	18	20	36	36	38	72
OCR-3	9	17	32	8	34	56
OSR-1	-	9	-	-	-	9
OMR-1	-	9	-	-	-	9
OSR-2	-	9	-	-	-	9
OMR-2	-	9	-	-	-	9
CITE	2	6	12	-	12	20
SSMEPF	-	1	1	-	1	2
SAIL	-	3	6	1	6	9
DRFC	*	*	*	-	-	8
CICE	1	6	-	-	-	7
CCS	+	+	+	+	+	+
HMF	-	2	5	1	5	7
KATS	-	-	-	-	-	1

* DFRC console enclosures are in place and will be populated with CLCS workstations.
+ CCS is under study, but will probably utilize a COTS utility control solution instead of CLCS.

Table 2-1 Workstation Equipment Allocations

The front room also contains large viewing displays for conveying information to all test participants. In addition, numerous time displays are provided for countdown time, hold time, universal time, and launch status displays. Table 2-2 identifies the timing display requirements for each OCR. The room also contains printers and other peripheral equipment, as well as sufficient storage and table surface area to support efficient processing operations.

Launch Status Displays
1 APU Hold Time Remaining
1 Post LO2 Drainback Elapsed Time
1 Time to T-0
1 Window Remaining
1 Hold Time Remaining
2 New (TBD)

Time Displays
Front Room Displays (4” version)
1 Universal Time
1 Countdown Time
1 Local Time

Side Wall Displays (2" version)
4 Countdown Time
4 Local Time

Table 2-2. Timing and Countdown Displays

2.2.1.1.1 System Engineering Console

Each CLCS System Engineering (SE) console contains one Command and Control Workstation (CCWS) and one Support Workstation (SWS). Each console also contains Operational Intercom System (OIS), Operational Television

(OTV), independent safing panel(s), telephone, and other institutional legacy equipment. Figure 2-1 shows a conceptual SE console.

The CCWS provides the human interface to the RTPS and allows operator control of GSE, vehicle, and facility end items (end items are both physical hardware and software components). The CCWS is a “dual headed” workstation (two monitors with a single virtual desktop working area) along with a single keyboard and mouse. The RTPS is fail operational with the exception of CCWS and some user test application software. Alternating CCWS are on separate power feeds to allow an engineer to move to an adjacent CCWS in the event of a failure on the prime CCWS. RTPS provides the mechanism for user test applications executing in a failed subsystem to be automatically initiated in a redundant subsystem, but the application determines whether the fail over is to an operational or safe condition.

The SWS provides the interface to support business and analysis processes which include access to legacy business systems, display of CLCS SDS data, and near-real-time data retrievals. The SWS is a conventional “single headed” workstation with its own keyboard and mouse.

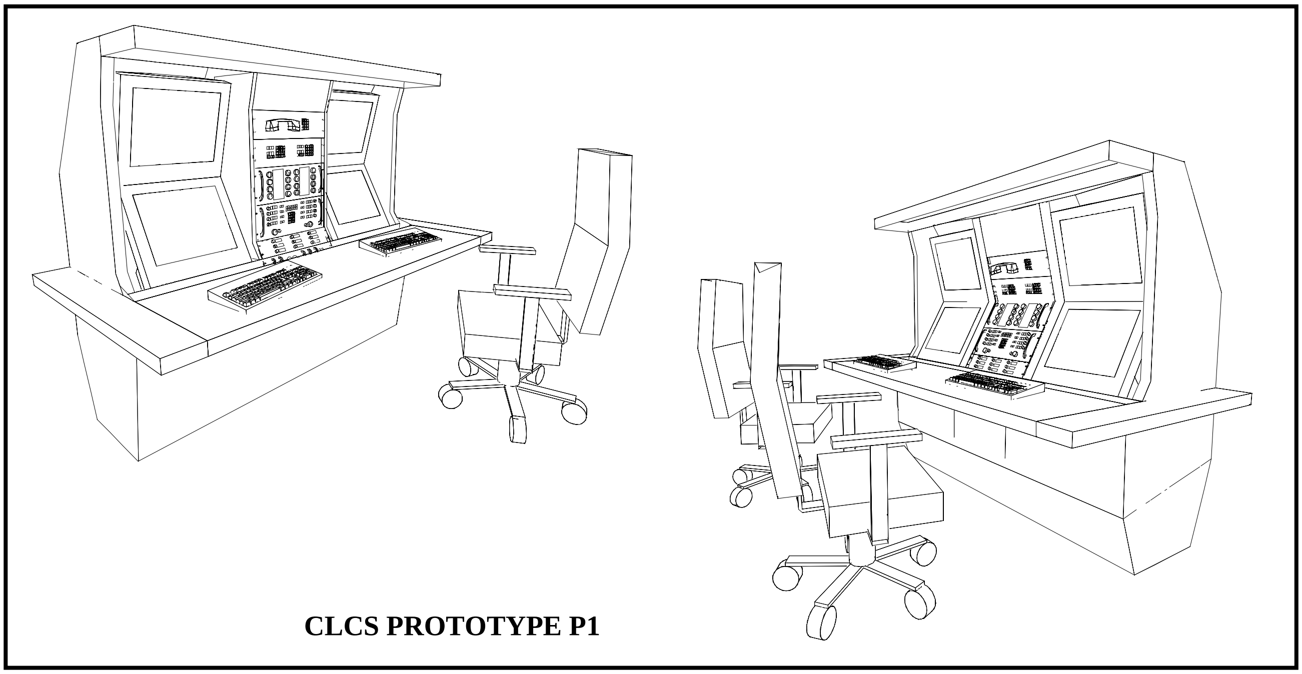

Figure 2-1. Conceptual System Engineering Console

The CCWS and SWS are connected to separate and independent networks to ensure separation of real-time control functions from business functions. This provides an additional level of security during Space Shuttle processing. A utility network connection is provided to facilitate shared access to peripheral devices from both command and business networks. Figure 2-2 depicts the functional connectivity of an SE console.

SE consoles are generic and can support any engineering discipline for any given test. The consoles are not associated with a single engineering discipline since all real-time displays (within a single test configuration) are resident and viewable at any console. The independent safing system utilizes generic panels that can be configured to support any system as needed. However, engineering disciplines are normally grouped within an OCR for test operations to allow those that require common interactions to be co-located. Major test operations use standardized console assignments to provide ease of communications for associated systems and familiarity in location.

A monitor-only capability is provided for management and support personnel during launch (i.e., similar to FR-2 in CCMS). These personnel access the same displays available on SE consoles, but have no command access.

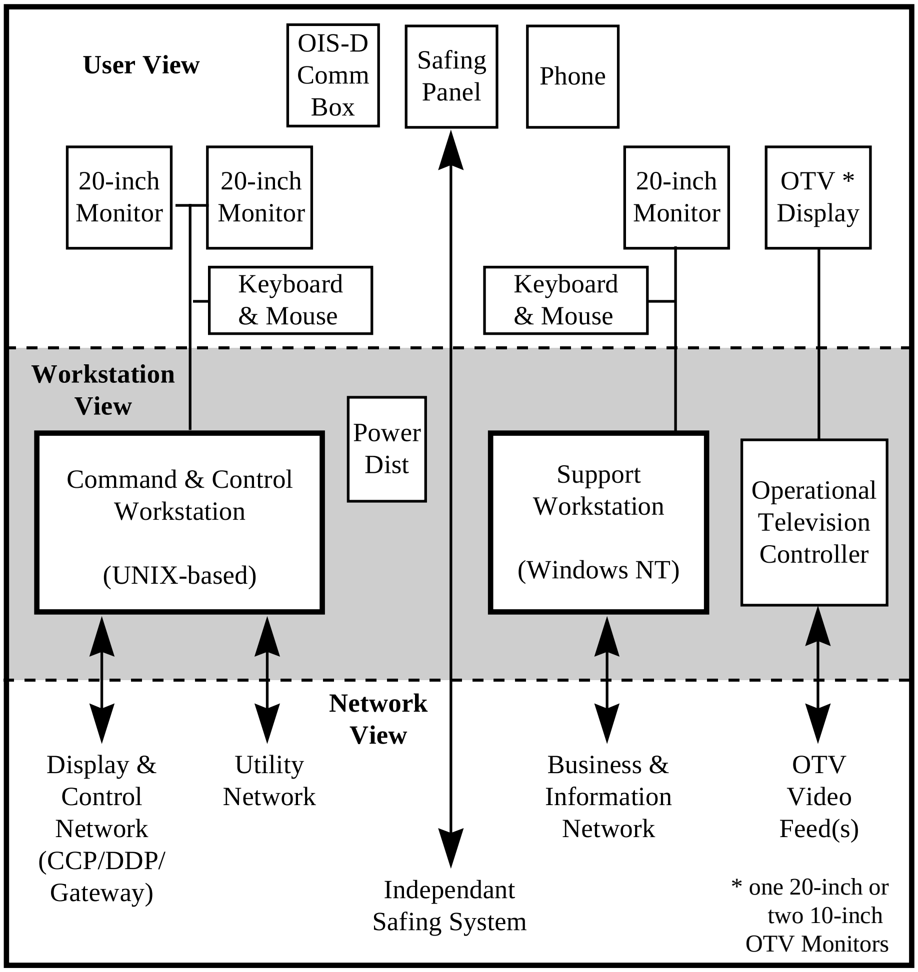

Figure 2-2. System Engineering Console Functional Connectivity

2.2.1.1.2 Test Director/Test Conductor Consoles

The Test Directors (TD) and Test Conductors (TC) perform a different function than systems engineers and therefore have different requirements for their consoles. In general, TCs do not have a need for the capabilities provided by a CCWS. Access to the business systems via a SWS is provided at each TC console, and space is allocated for OTV monitors. Provisions for such legacy equipment as OIS-D, RF OIS panels, Astronaut Communication panels, Paging & Area Warning Systems, Ground Launch Sequencer (GLS) hold switch, Emergency Camera Panel, Bird Deterrent Panel, and multiple telephones are also provided. Each TC console will be equipped with differing types and amounts of legacy equipment based on the job function it normally supports. Figure 2-3 shows a conceptual TC console.

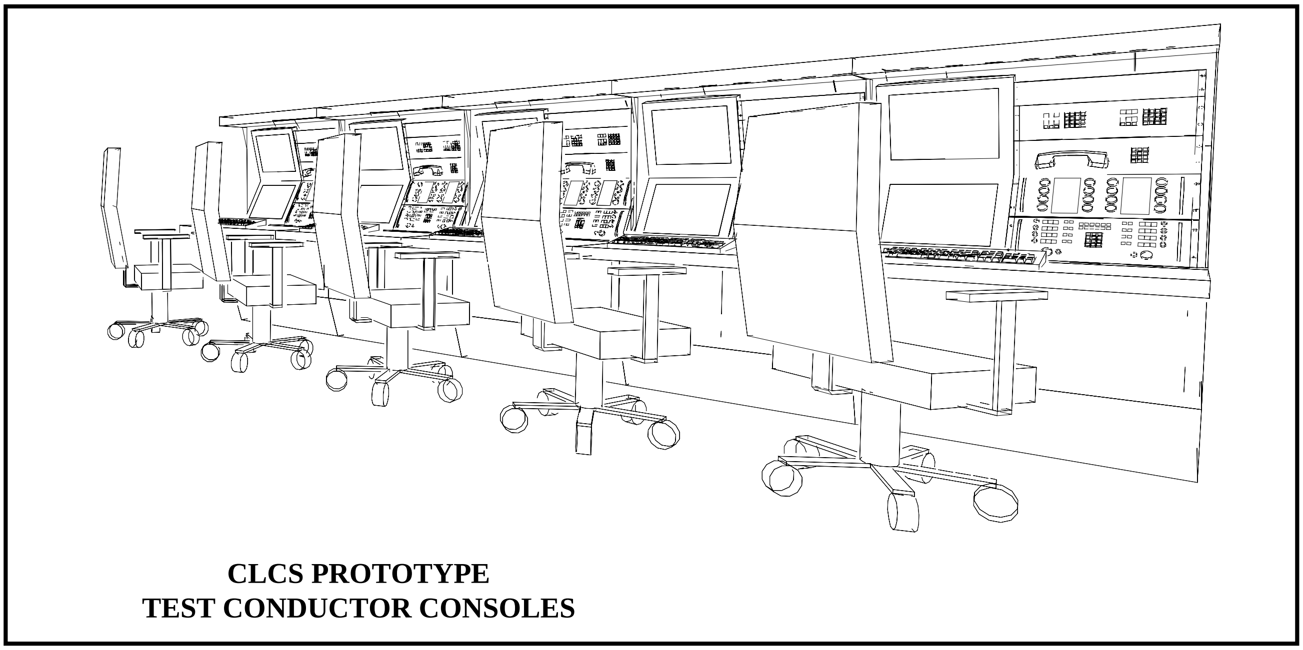

Figure 2-3. Conceptual TC Console

Each OCR will have two support modules equipped with CCWS in the TC area to provide Test Conductor access to command authority management tasks. Figure 2-4 shows the TC console functional connectivity.

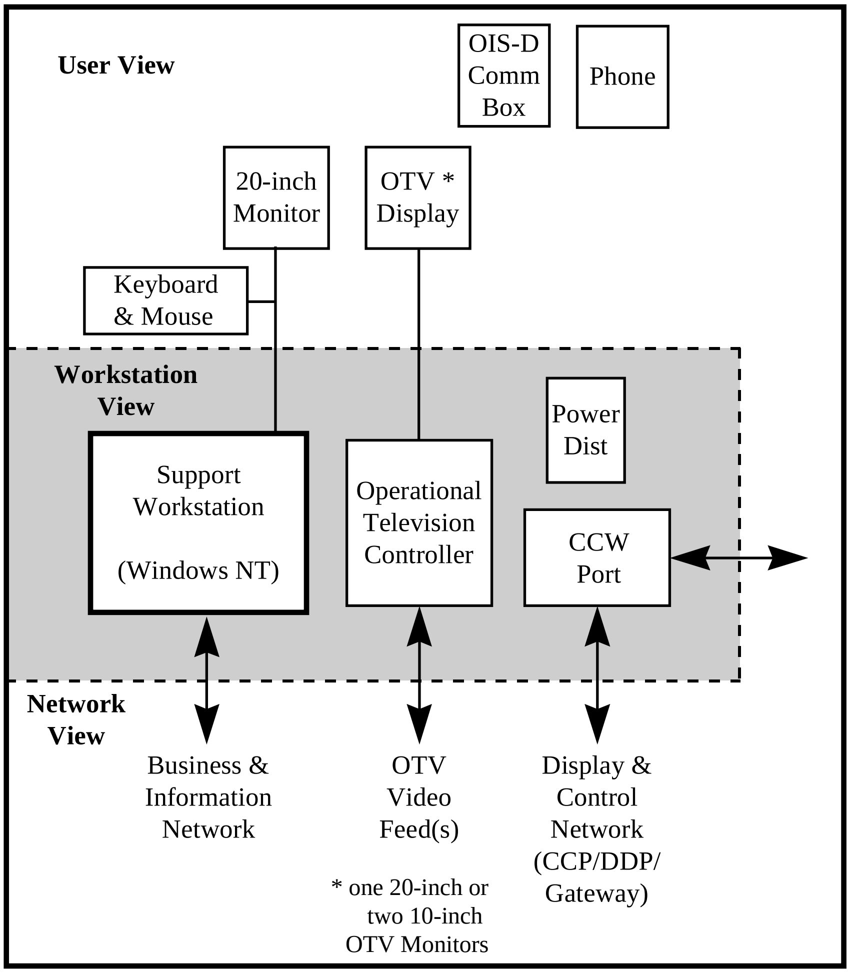

Figure 2-4. Test Conductor Console Functional Connectivity

2.2.1.1.3 Support Modules

Support Modules provide additional table surface area and space for an additional workstation. They also contain peripheral devices such as printers, facsimile machines, and scanners, as well as additional OIS panel(s). The support module is designed to augment day-to-day processing by providing this extra capability to the engineer, however it becomes necessary in the launch environment as an area for the system specialist to work and communicate with the engineering management supporting room. Figure 2-5 shows a conceptual support module.

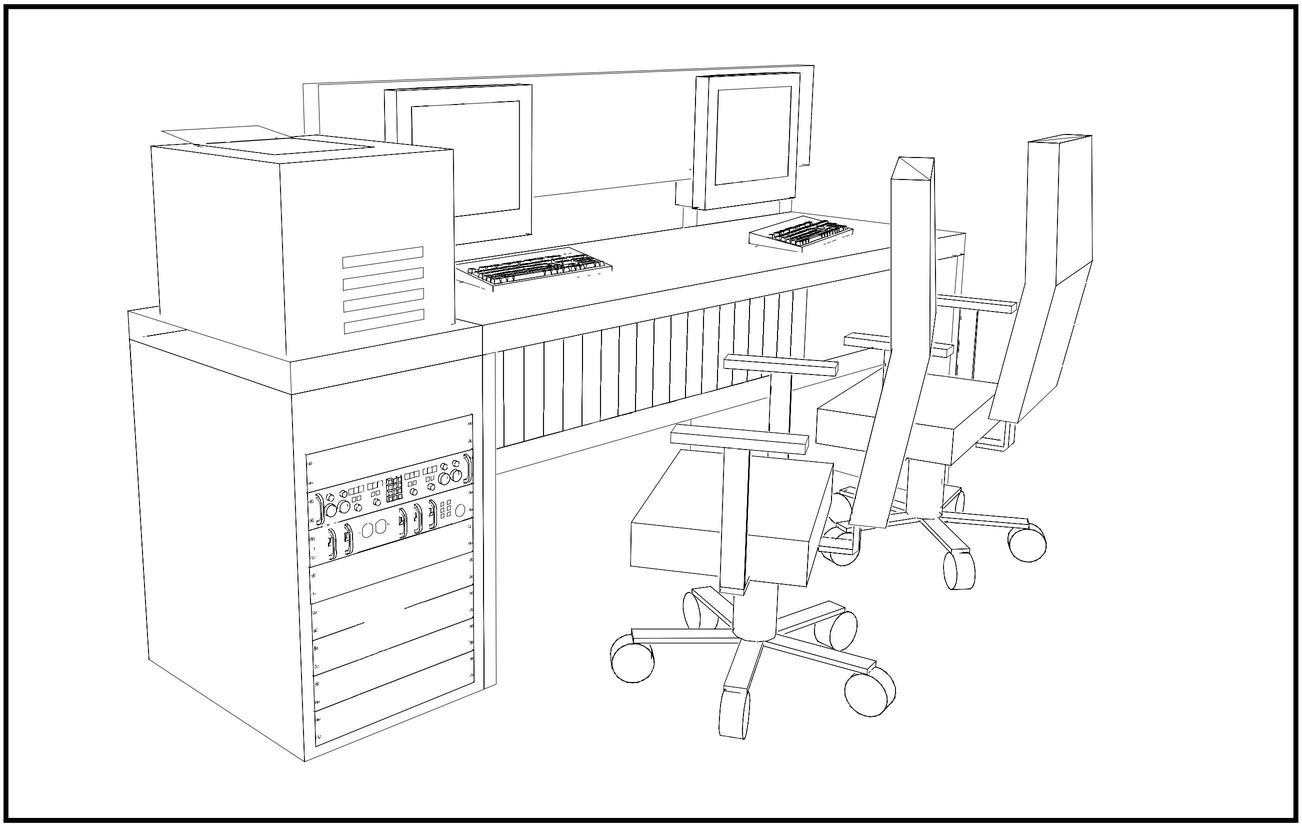

Figure 2-5. Conceptual Support Module

The support modules are generally equipped with a support workstation, although the two in each TC area have CCWS instead. Internal and external ports are available at the support module for expansion to include an additional CCWS or SWS, for laptop connectivity, as well as slave OTV monitors, OIS, and telephones. Figure 2-6 shows the support module functional connectivity.

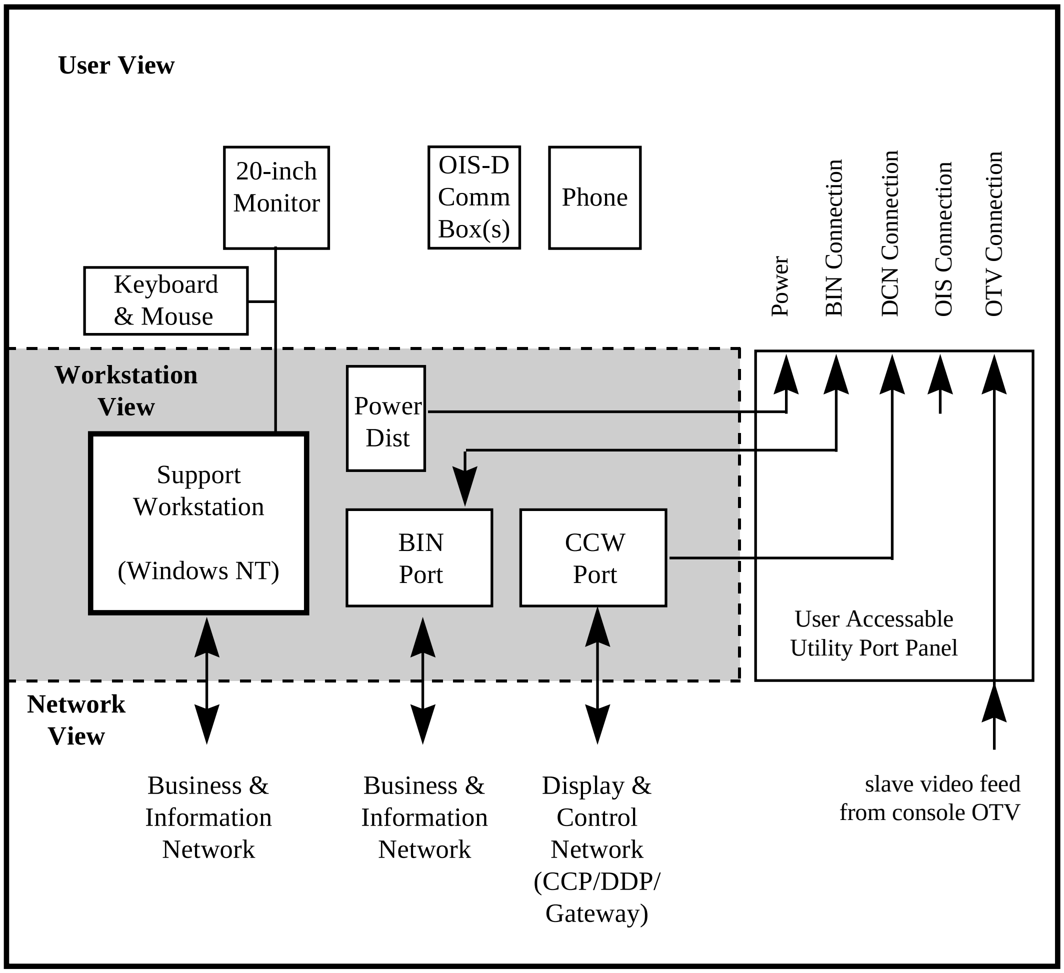

Figure 2-6. Support Module Functional Connectivity

2.2.1.1.4 Operations Management and Support Rooms

The Operations Management Room (OMR) and Operations Support Room (OSR) are located in enclosed areas at the front of OCR-1 and OCR-2. These areas have support modules with SWS that provide access to the business systems, along with legacy OIS equipment and telephones. Each support module is sized to seat two comfortably. OTV monitors will be placed around the periphery of the room in clear view of all those located in the rooms to provide visibility into processing activities.

2.2.1.2 Common Equipment Area

The areas behind the three Front Rooms are called the Common Equipment Area (CEA). This is where the Control Groups, Gateway Groups, air handlers, and power distribution units reside to support front room processing and local operations. The area is organized in such a way that the equipment in the CEA directly behind a particular OCR does not necessarily correspond to, or support, that OCR. Rather, the three CEA rooms can be considered one large collection of equipment - an important distinction within the context of a Test Set.

Two major types of equipment are located in the CEA. The first are the six gateway groups that consist of the front-end interfaces to the vehicle and GSE. The number of gateway groups was derived by associating an OPF gateway group with each of the three OPFs and a VAB/Pad gateway group with each of the three MLPs. This number supports processing of all the combinations of facilities, vehicles, and GSE within the three OCRs. Each of the six gateway groups is normally dedicated to a specific facility (OPF-1, Pad A, etc.), eliminating the need for the Remote Control Video

Switch used in CCMS. A contingency patching capability exists to allow a gateway group to support a different facility if the need arises. The other equipment type consists of Data Distribution Processors (DDP), Command and Control Processors (CCP), and network equipment known as control groups. There are eight control groups that can be allocated between front rooms and gateway groups as required to support any test scenario. This number is derived from the maximum number of TCIDs which need to be supported at any given time. See Table 2-3 for an allocation of gateway groups and control groups.

	Gateway Groups	Control Groups
LCC Set	6	8
SSMEPF	*	*
CCS	+	+
CITE	2	2
HMF	1	1
DFRC	0	0
KATS	0	0
SAIL	1	1

* The SSMEPF uses an LCC Set CEA.

+ CCS is under study, but will probably utilize a COTS utility control solution instead of CLCS.

Table 2-3. CEA Equipment Allocations

2.2.1.3 Shared Input/Output Area

CLCS introduces new functionality in the Shared I/O Area. Designed to serve as a data collection and review location, the Shared I/O area permits near real time engineering data analysis in an off-line office environment, but still with the proximity of the control rooms. Grouping this equipment in a common location minimizes the quantity of peripheral equipment necessary in the front room, and also serves to minimize background noise usually associated with high-speed printers, etc. The area allows room for conferencing as well as peripheral devices. The peripheral devices located in a shared I/O area include printers, copiers, scanners, strip chart recorders, and facsimile machines.

2.2.2 Central Operations Facility

The Central Operations Facility (COF) is an area located on the second floor of the LCC. The resource allocation, operations, maintenance, and troubleshooting of CLCS equipment is coordinated from this area. Co-locating these functions allows a synergy between the various functions, and also the sharing of talents and resources that might be in limited supply, especially during off-shift hours. In addition to the set master function, the operations of SDC are located in this area. Other functions will potentially be moved to this location if a cost/labor savings, or operational requirement, dictate.

2.2.3 Shuttle Data Center

The Shuttle Data Center (SDC) is located on the second floor of the LCC and is responsible for recording all CLCS test data, as well as various internal data (network traffic, etc.) necessary for troubleshooting. The SDC also contains the configuration-controlled software repositories for CLCS. The link level data recording functions previously accomplished in RPS have been allocated to SDC under CLCS, although this equipment will remain in a separate location on the second floor of the LCC.

2.2.4 Simulation Facility

The Simulation Facility is located on the second floor of the LCC and contains the Video Simulation Interfaces (VSI) used for link level simulation in CLCS. The VSIs were upgraded prior to the development of CLCS as a separate project. Subsequently, another effort was undertaken to re-host the Shuttle Ground Operations Simulator (SGOS) models to the new VSIs to allow the decommissioning of the Central Data Subsystem (CDS).

2.3 LCC SET FUNCTIONAL CHARACTERISTICS

Each OCR is configurable to support multiple processing flows and TCIDs, a capability described in terms of flow zones and test sets. The grouping of consoles associated with one particular TCID is termed a flow zone while the grouping of a flow zone along with its common equipment (gateway and control groups) comprise a test set. Test sets are monitored and supported by master/maintenance functions residing in the COF.

2.3.1 Flow Zone

A Flow Zone is defined as the group of consoles supporting any particular processing flow or TCID. The OCR is divisible into several distinct areas, one for each processing flow, providing the capability to command, control, and monitor multiple processing flows within the same OCR. Command paths between flow zones are logically isolated to those CCWS which support that flow. While logical isolation restricts an engineer from inadvertently commanding in the wrong TCID, physical clues (i.e., signs, display headers, etc.) are also provided to distinguish which flow the consoles are supporting. The number of consoles assigned to a flow zone is variable and can be expanded as testing needs increase and reduced when testing needs decrease. The test set master is responsible for assigning or removing individual consoles from a flow zone configuration.

The test set master, test conductor, or any system granted command assignment authority can authorize commanding at individual consoles as the need arises. A system engineer requests command capability as they report on-station and the test conductor assigns a location and modifies the commanding configuration as required. The command authorization task requires that the test conductor have access to a CCWS, two of which are provided in support modules located on the test conductor rows.

2.3.2 Test Set

A Test Set consists of a flow zone along with its associated gateway group and control group. Once established, this configuration is dedicated to support a specific processing flow or TCID. The test set provides links to control the vehicle and its associated GSE and to safe the vehicle (e.g. power down, propellant drain, etc.) and its environment (Pad, OPF, etc.). The elements of a test set are interconnected with two high-speed networks: the Real-Time Critical Network (RTCN); and the Display and Control Network (DCN).

The Real-Time Critical Network (RTCN) provides communications between the Gateway subsystems, the Data Distribution Processing subsystems, the Command and Control Processing subsystems, and the Shuttle Data Center. The RTCN implementation is fault tolerant to the extent that no single network failure will cause more than one processing subsystem to be switched from the active to the standby subsystem. The Shuttle Data Center records all network traffic on the RTCN. The SDC archives RTPS measurement data and provides retrieval capability to users. The SDC also uses the RTCN as the path for loading software and TCID’s into the control groups and gateways.

The Display and Control Network (DCN) provides the transmission means for communications between the Command and Control Workstations, the Data Distribution Processing subsystems, and the Command and Control Processing subsystems. The SDC records selected network traffic on the DCN. The DCN is also used for retrieving recorded data from the SDC and for loading software and TCIDs into the CCWS.

A single OCR is typically divided to support two non-integrated flows, although it can be divided in other ways to meet varied processing requirements. From the beginning of integrated operations, defined as the period from the Shuttle Interface Test through Terminal Countdown and Launch, an entire OCR is dedicated to support the prime integrated flow. For a portion of launch countdown, and certain launch countdown simulations, two OCRs will be configured to support the prime integrated flow to provide additional consoles for management support.

Figure 2-7 illustrates an OCR test set configuration for normal day-to-day operations. Figure 2-8 illustrates a launch countdown test set configuration. These figures do not accurately represent the floor layout, number of consoles, gateway and control groups or selection of the control rooms. They are only intended to identify the concept of grouping common equipment with consoles to form a test set.

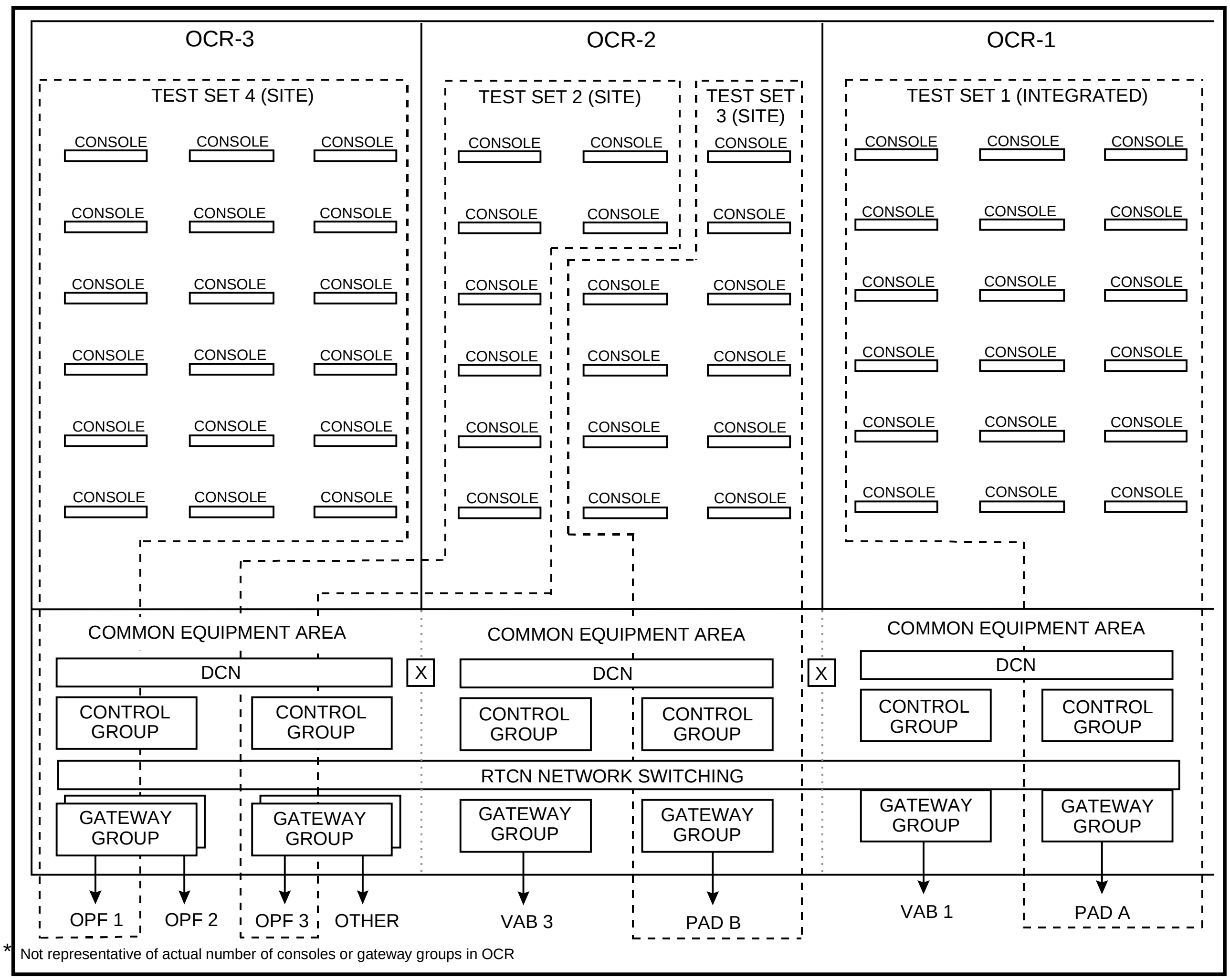

Figure 2-7. Nominal LCC Set Daily Operations Configuration

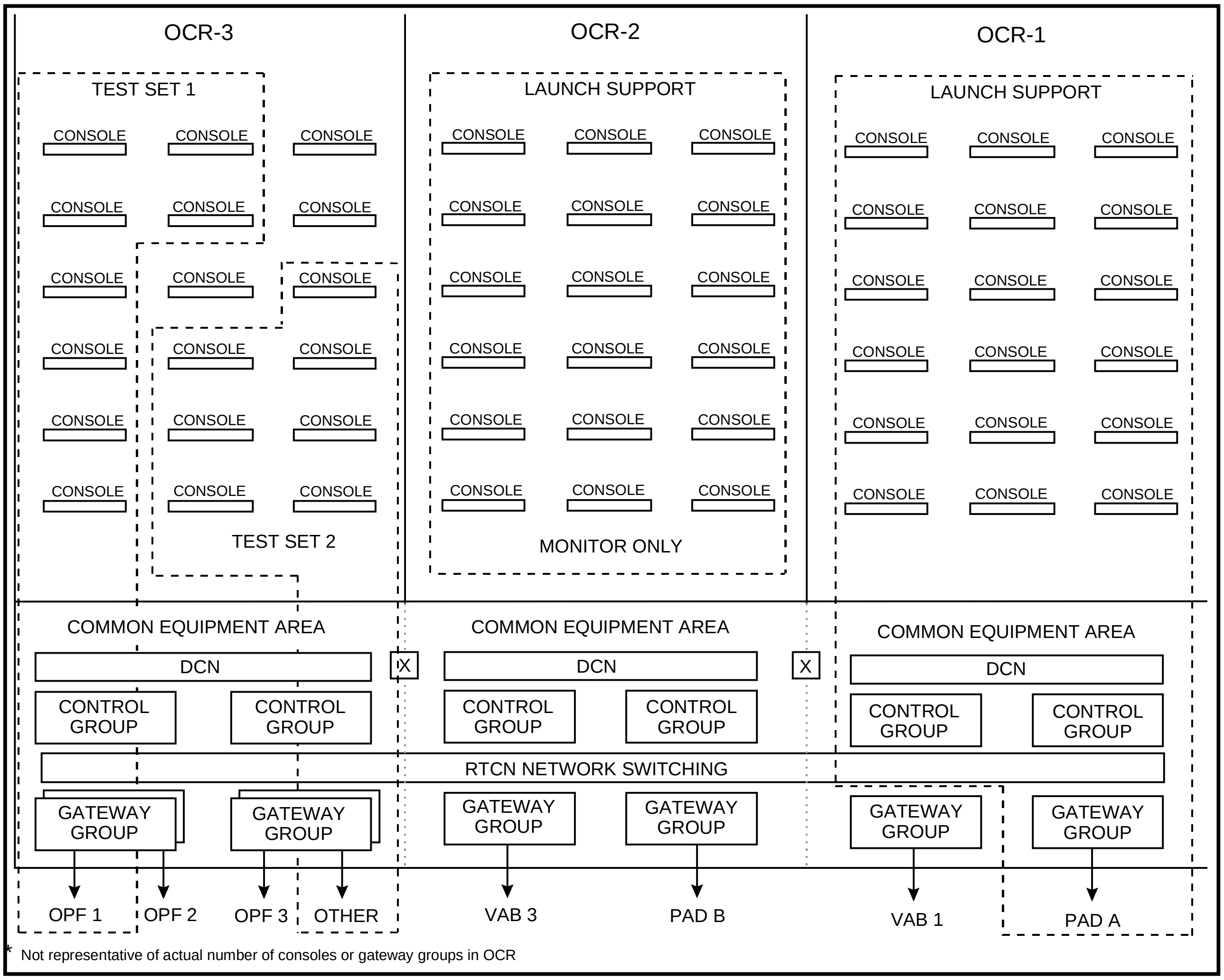

Figure 2-8. Nominal LCC Set Launch Day Configuration

2.3.3 Central Operations

The Central Operations Facility (COF) is a concept that brings together varying operations and maintenance functions to a centralized location. Systems in the Complex 39 area (e.g. RTPS, SDC, Simulation, CCS, etc.) will locate their twenty-four-hour-a-day operations and "network centric" functions in the COF. This centralization concept enables CLCS and other Complex 39 systems to take advantage of similarities of functions and expertise by forming a shared pool of experts and analysts capable of serving multiple systems. The COF is still in the early conceptual phase and is currently envisioned to be located on the 2nd floor of the LCC.

2.3.4 Shuttle Data Recording

SDC provides a centralized recording capability for time-tagged Shuttle processing data, RTPS configuration changes, error messages, system messages, inter-process communications, and other information. SDC provides the capability to record CLCS data and retrieve data that has been recorded. See Table 2-4. All data (both measurement and stimulus) to end items are recorded to SDC as processed engineering data with the capability to record raw counts as required. In addition, the SDC records all system traffic affecting end items or system configurations. Network traffic is recorded to the SDC to aid in troubleshooting. In the event SDC is not available, local logging is provided with the ability to download local logging data to SDC. In addition, SDC distributes RTPS data as a CLCS Shuttle data stream. SDC provides for the retrieval of any recorded data as requested. SDC also provides for the retrieval of existing CCMS data from archives.

	Data Link Recording Analog	Data Link Recording Digital	Packet Data Recording	Test Measurement and Message Data Recording
Launch Data Bus		Critical Operations	Gateway Output and Merged Stream	Merged Streams
Ground Data Bus		Trouble Shooting	Gateway Output and Merged Stream	Merged Streams
Orbiter FM	Critical Operations	Critical Operations	Select Data to RTPS	
Orbiter PCM	Critical Operations	Critical Operations	Gateway Output Merged Stream	Merged Streams
SSME PCM	Critical Operations	Critical Operations	Gateway Output Merged Stream	Merged Streams
Merged Data	Trouble Shooting	Trouble Shooting	Gateway Output Merged Stream	Merged Streams
RTPS Packets			All Operations	
RTPS Data			In Packets	Engineering Units all Operations as required
Engineering Data			In Packets	Engineering Units all Operations as required

Table 2-4. SDC Recording

Data link level recording, both analog and digital, provides the capability to record, retrieve, and playback PCM downlink and Orbiter FM signals. It also provides recording and retrieval for the LDB and ground data bus signals to aid in troubleshooting. CLCS provides selective access to this data in real-time from the RTPS and additional real-time viewing is provided in the SDC. Retrievals are provided as data files, tabular reports and plots. Additionally, data can be replayed for reprocessing by the RTPS.

Packet Data recording is used to record selective network traffic on the critical network within the CLCS system. Packet data is available on-line for up to 90 days for troubleshooting purposes, after which it will be archived. Retrieval application and products are similar to those provided by the CCMS Shared Peripheral Area (SPA).

Test measurement and message data recording is used to record all data related to the end items and its processing by CLCS. Data recording breaks apart the packets of data into the individual components (e.g., FD data, messages, etc.). The SDC then sorts, indexes and organizes this data for efficient retrieval. All data is available online for the greater of three flows of each vehicle or two years.

Link data and packet data are recorded with a universal time-stamp. Test measurement/message data are recorded using data stream time. For gateway supplied measurement data, data stream time is on an individual measurement basis (using the universal time when the measurement was collected). For other subsystem or message measurement data, time is the universal time when the data was generated. In addition, the universal time stamp of when packet data was placed on the network is provided. The embedding of universal time with the recorded data allows correlation between data received by the RTPS and events occurring within RTPS. The use of two time stamps supports correlation of end item events with other end item events and correlation of system events with each other.

Provided retrieval applications produce formatted dumps from packet data for selected time frames, filtered by types, data sources, and data destination. Other provided retrieval applications report all aspects of test measurement and message data, including higher resolution time and heath and status information. The data are available in the RTPS set and by way of a user-friendly interface to users at KSC and other NASA Centers.

SDC also repackages and distributes near real-time RTPS data as the CLCS Shuttle Data Stream (CSDS). This data distribution replaces the existing Shuttle Data Stream (SDS). The data distributed includes system messages, measurement and command data, and command responses. The CSDS is available on the CLCS business and information network, KSC office networks, other KSC processing sites, and approved off-site locations. The data is distributed in a manner that is compatible with the existing network infrastructure.

2.3.5 Simulation

The Simulation System provides support for the testing and validation of CLCS equipment; checkout and validation of software used in Shuttle ground testing and launch operations; training of CLCS console operators; and launch team training. The simulation system user has a model control interface and a data interface. After accessing the model, the model control interface provides a command entry interface to allow the user to: set Model modes, fail and reset data/stimuli, run procedures, status values, and trace model performance. The simulation system provides three modes of data interface: in the network mode, a connection is made to the model by accessing the data portion of the simulation interface from the local workstation; in the RTCN mode, the simulation connection is part of the configuration of the test set; and in the RTCN mode, the simulator appears to be the front end of the system. A fourth mode, the link level, connects the VSI simulation to the RTPS gateway groups. In this mode, model data appears as actual end items to the system. The simulation server permits a low-fidelity model to be available for the office environment for up to 25 simultaneous users. This support provides a fidelity level sufficient to provide initial software debug and initial operator training on single subsystem.

To support these activities, a number of master math models are available to provide integrated simulation support. Master math models include all planned and identified math model updates to support the respective TCID. The master math models, both debug and verified, are groupings of system models to provide the simulation support for related systems and activities. Debug master math models provide support for application software development and for training simulations (countdown, cryogenic loading, and hypergol loading).

There are four operational scenarios for simulations. Single system simulation can be performed from the desktop in an office environment. Debug of monitor application and display can take place on a SDE or IDE set using playback data. Smaller multi-system simulations and software debug can be run from an IDE or SDE using a simulation gateway without requiring link support from VSI. Software validation can take place in the IDE or section of an OCR using full link support involving multiple VSIs.

	Local Model	**Network Simulation**	**Simulation Gateway**	**Link Level Simulation**
Office	Initial debug	Initial debug		
SDE	Initial debug	Initial debug	Functional debug	???
IDE			Functional debug	Verification

OCR			???	Team training, S/W validation, set verification.

Table 2-5. Simulation Scenarios

In the office environment the developer has access to a set of development tools and a limited run-time simulation environment that allows interaction over the networks with current models or provides a limited local simulation. This requires little coordination by the developer to gain resources. In addition, special development tools are provided to allow modifications to the run-time environment in real-time for quick turn-around during the initial debug of application code.

A developer or user may schedule time on an IDE or SDE to test display and monitor programs. After loading the set, previous playback data can be requested to checkout new applications or help troubleshoot problems that were caused by the recorded data events.

Models from the simulation gateway can be connected to the test set to allow developers or users to perform most functional testing on application. The developers or users have control of the model as well as their application from their workstation position. The simulation system also supports individual system training by providing the capability to load either a single system or integrated model in a standalone training scenario.

To validate application software the developer and the user schedule an IDE or portion of an operational set. The IDE is configured the same as any other operational set. The test set's gateway group is connected to the VSIs which provide link level simulation. Actual operational test cases are run against the applications.

To perform a full application software test or full team training an OCR is scheduled. Full link level support is provided by the VSIs. Model performance and insertion of faults are controlled from the support workstations. The simulation system supports S0044 (Launch Countdown Simulation), S0056 (Cryogenic Loading Simulation), and S0066 (Hypergolic Loading Simulation) training.

2.4 LOCAL OPERATION DEFINITION

CLCS provides for local control of ground processing operations by extending the RTPS to the processing sites. The face-to-face communication with on-site personnel this allows is an important improvement to the control of operations. With CLCS, the engineer on the floor at the vehicle/processing site has the ability to directly monitor and command operations and perform troubleshooting in support of ground processing. CLCS local operations are not satellite control rooms like the specialized processing sites; in this context, the purpose is to carry the test to the vehicle which eliminates the need to have an engineer supporting the task from the OCR. It allows closer coordination with the task team working the job.

CLCS local operations include the ability to monitor and command flight and ground hardware from multiple places at various processing sites. This is accomplished by extending the required network(s) near vehicle and ground processing locations to support identified engineering requirements. The concept is scaleable with additional drops installed to meet specific engineering requirements.

This type of testing is applicable to locations in the orbiter or GSE at associated processing sites. It applies to both integrated and non-integrated vehicle and flight element testing, although integrated operations always require an OCR be operational and supporting the test. Local operations enables the engineer to see and hear the hardware react when commands are sent and reduces the need for engineers supporting concurrently at the control room and the test site. In addition, the capability will exist to add portable data acquisition test equipment to the local control workstations. SDC provides access for local workstations to store and retrieve data collected at the processing sites.

All network drops at a local site are initially enabled for monitor-only. This preserves the integrity of the RTPS and provides protection against inadvertent or unauthorized commanding of the vehicle or GSE. If command capability is needed (limited to the activity authorized for that location), activation by the TC in the OCR is required. An activation protocol will be established between the local user and the TC using OCR resources. Test conductors will manage command and control authentication of local operations.

Portable (e.g., laptop or mobile terminal) CCWS that provide monitoring and command capability are provided for use at the local sites. Configuration control of the CCWS being used at the local sites will be maintained in the same manner as CCWS located in the OCRs. It is anticipated that an engineer will check out a CCWS from a central location prior to reporting on-site at the local test. These portable CCWS provide the same functionality as a CCWS located in an OCR. They provide the capability to control both single commands and command sequences for the end item test being supported. Command actions on a local CCWS will be recorded at the same level as any other CCWS.

Use of local control for hazardous operations is procedurally limited, and will not be allowed if the loss of command capability increases the hazard or if potential exists for a hazardous area to expand to include the control location. The intention of local operations will be to primarily support single system element testing. Integrated operations can not be run strictly as a local operation and requires the support of an OCR.

2.5 SPECIALIZED PROCESSING SITES

Specialized Processing Sites are defined at those areas outside the LCC set where CLCS activities are performed. These include the:

1. Hypergolic Maintenance Facility (HMF)
2. Cargo Integrated Test Equipment (CITE)
3. Complex Control Set (CCS)
4. Space Shuttle Main Engine Processing Facility (SSMEPF)
5. Dryden Flight research Center (DFRC)
6. Shuttle Avionics Integration Laboratory (SAIL)
7. Kennedy Avionics Test Set (KATS)

Sufficient numbers of SE and/or TC consoles are deployed or, at a minimum, connectivity to CLCS is provided at these sites to support testing requirements. Refer to Table 2-1 for specific resource allocations. CLCS will provide the same network and safing capabilities at these sites as identified for the OCRs.

2.5.1 Hypergolic Maintenance Facility

The Hypergolic Maintenance Facility (HMF) is located in the KSC Industrial Area and consists of three test cells and a single control room.

The HMF is used to perform repairs and checkout on the OMS Pods and FRCS Modules. The pods and modules undergo major refurbishment at the HMF while the associate orbiter is in its maintenance down period. Also, when hardware failures occur within the OMS/RCS system, a pod or module is removed from the orbiter and brought to the HMF for repair. The HMF CLCS control room supports all three test cells simultaneously with up to five parallel tests.

The HMF has no data bank changes from one flow to the next except infrequent mods (every few years). Therefore, the same TCID is used from one flow to the next. Usually, the only driver for TCID changes is operating system updates.

Complete TCID changes for the HMF should be kept to a minimum but under no circumstances more than one or two changes per year. However, the capability must exist to update application software or add application software without reloading or rebuilding the entire TCID. This requirement is similar to today's "50 kilobit" capability.

TCIDs would normally be built in the PCC or similar work area. The TCID must then be transmitted to the HMF to be loaded. The HMF also supports software debug and verification against the simulation system. The TCID may also be loaded in the SDE or IDE for software debug or verification.

2.5.2 Cargo Integrated Test Equipment

The Cargo Integrated Test Equipment (CITE) set is located in the SSPF and consists of two test sets that support payload and International Space Station (ISS) operations. The CITE sets are connected to test stands located in the SSPF and the VPF. The SSPF CITE system provides for checkout of horizontally oriented payloads and the VPF CITE system provides for checkout of vertically oriented payloads. Each test stand has a full set of Orbiter avionics required to support payload checkout.

The CITE test sets have sufficient resources to simultaneously support two of the following operations

- payload flight hardware interface verification in the CITE test stand located in the SSPF
- payload flight hardware interface verification in the CITE test stand located in the VPF
- monitor the health & status of a payload end item integrated into an Orbiter payload bay
- support mission unique application software development
- support ground software and flight software testing

The CITE TV monitors are on a local CCTV switcher. The selection of the CCTV inputs is the responsibility of CITE operations. The monitors and control panels are special for CCTV and will be relocated into the CLCS consoles. CCTV control from the support workstations is not required.

CLCS supports the TCID build process, the math model build process, and data bank build for payload and ISS operations. Payload function designators are added to the data bank by processing the Shuttle Data Tape. It is planned that future data bank requirements will include the ability to utilize input sources other than the Shuttle data tape products. CITE specific TCIDs are developed on a per mission basis to support application software debug, verification, and validation.

CITE application software development is performed on a multi-flow basis, with as many as five flows in various stages of development and test support.

2.5.3 Complex Control Set

Currently, the Complex Control Set (CCS) supports KSC facility operations 24 hours a day, 7 days a week. The CCS is located in the Complex Control Center (CCC) located on the first floor of the LCC. All 60 Hz Power, HVAC, Pneumatic, Water & Waste systems operated on KSC are centralized in the CCC and controlled by the CCS.

Operations related to vehicle processing that are time critical and independent from the operation of other facility systems are also performed in the CCC. Vehicle processing related operations in the CCC include:

- Pad Water-Acoustic (Sound) Suppression and Firex preparation and operation

- Pad Power-DC power supply for monitor and control
- Pad HVAC-Pressurized within the MLP and PTCR
- OPFs-Hypergolic exhaust fan operations
- O2 monitoring-verify and report readings (specific areas)
- CCF pneumatics-verify commodity supply exceeds duration of need
- LC-39/CD&SC power-report anomalies, duration of support after failure, effects of failure, alternative configuration (LCC, OPFs, and Pads)
- Pad elevator lockouts

While the exact implementation method for CCS remains under study, the leading CCS solution entails the replacement of the existing software, computer equipment, and communications networking with COTS equipment and software. This includes the replacement of all HIMs and RTUs currently used by the CCS with “programmable” Facility Interface Controllers (FIC). The other option is to use a variation of the system being developed for CLCS.

2.5.4 Space Shuttle Main Engine Processing Facility

The Space Shuttle Main Engine Processing Facility (SSMEPF) located next to OPF-3 will replace the existing SSME Shop located in the VAB. This specialized processing site provides turnaround maintenance, modification and checkout of engines at KSC. Currently this is accomplished utilizing the Command and Data Simulator (CADS) for command and control and a data link to LPS via the KATS Lab EIU for real-time monitoring, data recording and system performance analysis. SDS is utilized as a source for unique data reduction tools both locally and off-site. CLCS will replace the command and control function currently performed by CADS utilizing a Gateway Group and Control Group located in the LCC.

The SSME Controller (SSMEC) has unique I/O requirements for the command and data streams. Whatever system is used, it must provide the necessary I/O to interface with CLCS. The KATS Lab will eventually be phased out of operational support for SSME processing.

2.5.5 Dryden Flight Research Center

The orbiter landing recovery team uses support workstations at DFRC to monitor vehicle data during turnaround operations following a DFRC landing. Orbiter data is routed to KSC for processing and then routed back to DFRC via the CLCS Shuttle Data Stream. All ground equipment is manually controlled and Orbiter systems are configured via onboard switches and keyboard. The orbiter command interfaces are not active. Access to KSC business systems are provided at support workstations. Local (non-KSC) communication and television equipment is installed in the consoles.

2.5.6 Shuttle Avionics Integration Laboratory

The Shuttle Avionics Integration Laboratory (SAIL) is located at the Johnson Space Center, near Houston, Texas. SAIL interfaces with a flight-qualified set of Space Shuttle avionics to allow the testing and verification of CLCS system software and hardware, as well as CLCS test applications. Of primary interest is software that directly communicates with or controls the avionics components via the LDB, uplink, and PCM data busses. Testing at SAIL is required to verify the final timing and protocol interface requirements against actual flight-qualified hardware (as opposed to simulators at KSC).

CCMS made extensive use of SAIL during the early development and integration efforts. It is anticipated that CLCS will also make extensive use of this facility as the avionics interface equipment comes on line and new application software is developed.

2.5.7 Kennedy Avionics Test Set

The Kennedy Avionics Test Set (KATS) located in the VAB provides testing and support for performance of pre-flight validation of Shuttle avionics flight hardware in both standalone and integrated environments. KATS supports Mass Memory Unit (MMU) operations, LRU troubleshooting, and SSME Shop activities which include SSME Simulation and EIU support. CLCS provides RTPS connectivity to support local operations only.

2.6 SUSTAINING ENVIRONMENTS

CLCS is expected to support the Space Shuttle program well into the next century. A robust sustaining engineering environment is required to keep CLCS current with the state-of-the-art, as well as provide in-depth troubleshooting and enhancement capabilities.

2.6.1 Satellite Development Environment

The Satellite Development Environment (SDE) and Integrated Development Environment (IDE) are areas outside the OCRs where CLCS hardware and software are developed and tested prior to release for use in actual test operations. Four SDE and two IDE areas are provided to support hardware and software development and sustaining activities.

The SDE provides all the capabilities necessary to facilitate CLCS development and initial testing. The four SDEs are:

1. SDE-1: Used for the development of system software and hardware in an environment with informal configuration control. It consists of development and operational workstations, networks, real-time processors, and gateways.
2. SDE-2: Used for the development of system software and hardware in an environment under formal hardware configuration control.
3. SDE-JSC: Used for the development of system software at JSC in an environment with informal configuration control. It contains the same hardware as SDE-1. This SDE is operational during the period of CLCS development only.
4. SDE-Users: A set of development workstations in the Processing Control Center (PCC) and Operations Support Building (OSB) that permits the development of applications software and associated documents in an office environment. This environment is supported by configuration management servers located in the controlled environment of SDE-1, SDE-2, and the SDC.

In addition to the SDE areas, there is a development environment for simulations that provides a desktop capability. The development environment for simulations provides a stable execution system and configuration to develop and sustain math model applications.

2.6.2 Integrated Development Environment

The IDE provides a system where software can be tested against a stable hardware and system software configuration to support certification of System Software and validation of Application Software during CLCS development. The two IDE areas are:

1. IDE-1: A set of actual CLCS ‘production’ hardware in a test environment under formal configuration control. The set is configured like the hardware deployed in an operational environment to support application software validation and user acceptance. In order to maximize productivity the IDE will have access to all development/debug tools, languages and compilers used by Application Software to do development and test. The capability will exist to make a change to software from the IDE to correct

problems encountered during testing and resubmit, through the proper CM controls, to immediately get the test configuration updated with the change to continue testing of the application.

2. IDE-2: A second set of CLCS hardware in a test environment under formal configuration control configured as a real set to allow system checkout.

The two IDEs will be combined into one software development area (Ground Software Production Facility in the PCC when LPS is no longer supported) post CLCS development to support sustaining of CLCS Application and System software.

The CLCS sustaining IDE consists of a minimum of 19 Console Positions. Sixteen console positions are provided for application software development with full hardware compliment (DDPs, CCPs, Gateways) to support 2 strings. 3 Generic Test Facility (GTF) positions are provided to support system software validation with full hardware compliment to support 1 string. Capability exists to increase the number of console positions if needed in the future. Any console can serve as Master with the capability to support all strings from one Master Console (includes both App SW strings and GTF). Consoles will be the same as is in the Control Rooms with the same configuration (Dual headed workstations, OIS, and BIN) to support software development and system engineering training. Strings can be combined into one string when larger set is needed (S0044 support for example). Printers and phones will be provided in the same ratio as the Control Rooms to support development and training. Additional outlets and connectors to the BIN will exist to support laptops (on Support Workstation). Developers will have access to software development tools.

3. CLCS OPERATIONS

This section discusses both the CLCS support infrastructure and test operations. The support infrastructure consists of those activities that provide the framework for test operations. Test operations are those activities which are directly responsible for controlling and monitoring Space Shuttle processing with CLCS.

For the purpose of this document the word “hazardous” means that the loss of CLCS during a test would increase the risk of injury to personnel or damage to hardware.

As a minimum, the entire system will provide fail-safe capability. Specifically, all console workstations must be fail-safe. Primary critical equipment, such as gateways, processors, and network components must be fail-operational. This redundancy must be provided for critical command and data paths before CLCS can be used to support hazardous operations.

Real-time RTPS data via the CLCS SDS will be available to all operational CLCS locations, as well as various external NASA Centers and contractors. There should be no restrictions on shipping data to any NASA or contractor facility. CLCS has a capability to restrict displayed and recorded data on the network during impoundment periods caused by incidents or contingencies. Access to the command network is restricted to control rooms and authorized (on a case-by-case basis) local operations sites only. The business system interface is isolated from the command and real-time data networks.

3.1 SUPPORT INFRASTRUCTURE

The support infrastructure provides the resources to support the RTPS test set during test operations and provides auxiliary services as required.

3.1.1 Network Management

Network Management is responsible for the management, configuration, and monitoring of all CLCS-provided network components. It provides health and performance data and provides the control mechanisms for permitting or limiting access by all external network interfaces on a test set or OCR boundary. Any network related problems are detected by network management which provides support personnel the information necessary to perform operational reconfigurations. Network management also provides performance and configuration data for use in load balancing, system tuning, and both proactive and reactive fault isolation and repair. As it relates to the organizational level maintenance activities, network management works in conjunction with other commercial products and tools to control, reconfigure and repair faults within the network segments.

3.1.2 RTPS Control

Control and monitoring of the RTPS involves various hardware, software and human resources to ensure the peak performance of all test sets. These infrastructure-control related activities are integral in providing a successful test platform for vehicle and ground processing.

3.1.2.1 System Integrity

System Integrity performs health and status monitoring of all resources allocated to a particular test set, and performs redundancy management of all active/standby subsystems. It validates subsystem health and, based on system configuration, commands active/standby switchovers for failed redundant components. Additionally, it reports significant changes (e.g., data validity changes, subsystem configuration changes, etc.) within the test set to the appropriate destination resources. Utilizing a system viewer, the data provided by system integrity and subsystem integrity allows the monitoring of both overall system health and status, and detailed resource health and status. Graphical displays allow the user to select the desired level of detail. All system level health and status information is also recorded in the SDC.

3.1.2.2 Subsystem Integrity

Subsystem Integrity is incorporated within all subsystems within the test set, and provides health and status information for health monitoring and redundancy management decisions. It also records the health and status data to the SDC and routes error and informational messages where appropriate. Each message is annotated as to the test set and subsystem that the message originated from, and the time and date of the message occurrence. The message also contains an identifier of the software component originating the message.

3.1.2.3 Checkpoint

Checkpoint tracks and/or restores subsystem state information of selected subsystems within a test set. Checkpoint provides ongoing (continuous) and snapshot (demand) state information request capabilities, and allows a subsystem to be restored to a specified state.

3.1.2.4 HIM Scan Interface

The Hardware Interface Module (HIM) Scan Interface, upon operator command, snapshots the command stimulus values from a specified HIM. It provides updates to the stimulus values to the necessary test set resources, and provides changed HIM command stimulus data values for operator notification.

3.1.2.5 Operational Readiness Test

Operational Readiness Test provides the capability to safely test system resources. These tests provide a “level of confidence” that a resource is properly configured and ready to support in an operational environment. These tests exercise the software and hardware interfaces that are utilized when the resource is functioning in an online, operational environment. Specific restrictions are incorporated so that testing of resources that are directly connected to an end item do not adversely affect the end item itself.

3.1.3 Maintenance Monitoring and Diagnostics

The CLCS maintenance methodology is a broad-based approach to organizational level maintenance which utilizes system performance and failure data, on-line and off-line diagnostics, and software tools in order to isolate the majority of all non-intermittent faults to the Line Replaceable Unit (LRU) level. Generally, an LRU is a circuit card, power supply, network or computer box, printer or other assembly whose repair is not practical within the on-line environment.

Maintenance monitoring is dedicated for maintenance use, and provides several capabilities. It serves as a central point to run both intrusive and non-intrusive diagnostic testing on all command and control, and network resources within the LCC Set. The software allows intrusive testing only on those resources which have been released and de-configured from an operational test set. The diagnostic functionality provided includes the ability to capture and log system boot up processes for use in diagnosing subsystem failures. It collects time-tagged operational failure and health data from network management, set master and test set master resources, and includes data such as system messages, subsystem health and status data, network statistics, and results information from operational readiness tests. This operational and diagnostic failure data, used in conjunction with analysis software, provides a comprehensive fault isolation tree to guide maintenance personnel through the troubleshooting process. Maintenance monitoring is also used to provide advisory recommendations to the set master and appropriate test set master(s) concerning components that have not yet failed completely, but are operating in a reduced or degraded fashion. In addition, browsing capabilities of historical and reference database sources allow user research of failure data and LRU histories.

For those resources which are unable to communicate with maintenance monitoring due to primary network related problems or other faults, local diagnostics residing on each subsystem are used to isolate faults. These diagnostics are a collection of vendor and custom designed tools, utilities and fault isolation processes. Disk-based, time-stamped error logs and vendor supplied power-on self test functions, residing on each subsystem, are used to provide additional insight. Further, connectivity is provided from the console port of each subsystem in order to interface with maintenance monitoring to capture boot up failure processes and other messages which may be routed to the port. This ensures that valuable failure data, which would otherwise be lost, is preserved for diagnosis/evaluation.

3.2 TEST OPERATIONS

Test operations encompass the activities required for support of vehicle, GSE, and facility processing. It consists of test control that configures resources to support real-time operations; resource allocation which restricts command access; application start/status which allows users' access to the various viewers and displays; command/monitor application which provides authorized CCWS to issue commands to their respective end items; and data recording and retrieval which provides mechanisms to store and access the data produced during testing.

3.2.1 Test Control

Consoles supporting a specific TCID are grouped in a designated area within the OCR to allow maximum flexibility in the use of hardware and personnel while reducing the number of idle consoles. The test set is configured, loaded, and initialized by the test set master prior to test engineer and vehicle test conductor access. The CCWS within the test set are initialized in monitor-only mode until the proper console allocation and command authorizations are established by the test set master or the test conductor.

3.2.2 Resource Allocation

Resources are allocated from the set master located in the COF to each individual test set within the LCC Set. Once allocated to a test set, the resources are managed by the test set master. When the test set no longer requires the resource, it is released back to the set master for maintenance or reallocation to a different test set.

3.2.2.1 Console Allocation

CLCS provides a concept called "User Class". A user class is title given to a grouping of common functionality. For example, the functionality providing control of the Shuttle electrical power system is supported by the EPD User Class. A user class exists for each of the Shuttle engineering disciplines, for CLCS operations personnel (e.g., master, set support, and maintenance are all unique user classes) and for other functions within CLCS.

CLCS provides an interlock to preclude "User Classes" (i.e., engineering disciplines) from affecting end items outside their area of responsibility. Although users can view all data/displays, they can only command/control the components that they have been granted the specific authority to access. An authentication process ensures resources are only accessed (commanded) by authorized CCWS(s). The process consists of two components:

1. Console Allocation: the allocation of CCWS (zero through many) to one (or more) logically defined user classes.
2. Command Assignment: the assignment of a user class, user classes, or no user classes to a commandable end item.

All CCWS (except for the test set master) are initialized without command capability. A CCWS without an associated user class assigned to it is in “monitor only” mode. Monitor only CCWS cannot issue commands, but may be used to view, plot, receive messages, status, make data hardcopies, etc. Users must make a verbal request, via recorded OIS, to the console allocation agent (e.g., test set master, test conductor) to be granted specific access to resources. OIS is also used at the completion of a test when the allocated resources are relinquished.

The CCWS display provides the user insight to the Console Allocation that has been granted to a particular workstation. When a user attempts to issue a non-authorized command (by any mechanism), an error message is generated and logged. No manual “override” is available to change console allocation; it must be granted by an authorized agent.

Console allocation provides the capability to configure the test set to a predefined configuration (e.g., standard power up, launch countdown, hyper-load). Multiple consoles may be assigned the same user class (e.g., many LOX consoles may simultaneously exist). A single console may be granted access to as many user classes as required (e.g., DPS, INS EPD, ECL and ECS can reside at one console).

Provisions are available to quickly reassign console allocations (when operational needs arise or when a CCWS or SE console fails). With a predefined layout (used for major test operations), this reassignment precludes a loss of system control. For example: a failed CCWS user class can be assigned to an adjacent workstation with the operator moving only a few feet.

A controlled access method (i.e., password) is provided for the test set master who initially enables the test set. This method is used only when enabling an inactive test set (i.e., passwords are not used at each shift change when the test set remains active). The access method controls initial system access and is not used to identify the person performing the work. When the test set has been enabled, support operations personnel perform load and initialization functions.

Users do not possess a “log-in” for the CCWS (except for the test set master) and no operational requirements exist for the automated recording/association of which user issues what command. Existing procedural methods, including OIS discipline/recording, operational discipline, logbooks, and Work Authorization Documents (WAD) are used to determine who did what.

3.2.2.2 Command Assignment

Command Assignment associates a User Class to a group of commandable end items. This associates a user class with a group of test applications all the way down to a set of function designators. Users request through the command assignment agent (typically the Test Project Engineer) additional access to control end items. No manual “override” is available to take command assignment; it must be granted by an authorized agent.

A default association of commandable resources to user class is provided by the data repository (DBSAFE). The system supports the ability to have multiple user class access to the same end item resource (e.g., TPE and ECL would have controllability to orbiter cooling). The ability to remove access to an end item (or FD) is also provided. This capability is desirable to preclude the issuance of certain commands (the command assignment agent can reestablish control when required).

3.2.3 Application Start and System Status

Users may utilize the CCWS in monitor-only mode or, after acquiring the required permissions, may perform end item testing. The user may access all applicable command and control components (i.e., viewers, control programs, safing, etc.) available to that console position. Program initialization commands are initiated by the user from graphical selection mechanisms using either a keyboard or pointing device or via keyboard entry from the command entry area.

3.2.4 Command/Monitor Application

End item and function designator commands are initiated by the user from graphical selection mechanisms using either a keyboard or pointing device or via keyboard entry from the command entry area. Commands are type and range checked regardless of user initiation method. After appropriate application programs are initiated, the user can: monitor test operations; control testing (start, stop, bypass, abort); change configuration if necessary; respond to messages; report and solve problems; and terminate testing (this is not an all inclusive list).

3.2.5 Test Set Support Activities

Typical support activities include the loading or reloading of a TCID into test set resources in order to update the current software and provide the capability to reconfigure the test set from one TCID to another. Software controls and monitors the health and status of all test set resources and performs the redundancy management of all active/standby subsystems. Upon detection of a failed test set resource, spare resources are configured into the test set, their operational readiness to support test operations is verified, and they are placed into an operational state. Organizational level maintenance activities, controlled from a centralized maintenance area, initiate repairs and restore the resources to their functional status. Additional support activities include verifying of Hardware Interface Module (HIM) command states, the capturing and restoring of test set resource state information for resource failure recovery, and other activities required to support test operations.

3.2.6 Data Recording and Retrieval

The Shuttle Data Center (SDC) is a centralized resource which simultaneously provides support to all operational RTPS activities. Allocation of the underlying recording resources to specific tests is according to approved test schedules. The SDC OPS/CM function allocates, loads, connects and starts the supporting services prior to the beginning of a test. Communication between the Data Recording Ports (DRP) in each test set and the allocated SDC Recorders is initiated by the RTPS set under control of the set master function. In OCR test sets fully redundant data paths and SDC recorders support major tests. Each DRP provides buffering of the data to ensure that transmission errors or failures between the DRP and the SDC do not result in lost data. For each test set continuous monitoring of the SDC recording process is provided by the RTPS DRP and is reported to the System Integrity function. All Data is recorded in the SDC in packet form as received and for change data and messages in an expanded, indexed form to facilitate rapid retrieval. For major tests, or as required, two copies of both of these types are recorded. Backups to highly reliable tape systems are performed periodically. According to schedule, data for each test is archived to tape in a hierarchical managed process.

The SDC continuously provides access to retrieval processes for all test data. Both near real-time test data and data from previous tests may be retrieved from any workstation having connectivity and from applications programs executing in processors or servers having connectivity. Data retrieval requests originating in RTPS test sets on either the CCWS, SWS, or CCP are given priority over requests from other users outside of RTPS sets. Test data for each vehicle is kept on line for three flows (approximately 2 years) and selected countdown data for each vehicle is kept on line for all flows. Data not on-line is kept near-line and is available for retrieval without manual intervention.

SDC applications servers execute Advisory Applications and other user applications which have access to the CSDS, as well as retrieval functions, to provide data analysis in support of testing and troubleshooting. These applications are accessible from the Support Workstation. Some of the Applications may require prior scheduling, while others are available on an ad hoc basis.

4. SUPPORTING PROCESSES

Supporting processes consist of the tasks pertaining to the build, definition, loading, and maintaining of CLCS software and the processes required to support the CLCS hardware. The Supporting Processes can be broken into four major processes: 1) the Test Configuration Process, 2) the Hardware Sustaining Process, 3) the System Software Sustaining Process, and 4) the Application Software Sustaining Process. Each of these is discussed in detail below.

4.1 TEST CONFIGURATION PROCESS

The Test Configuration Identifier (TCID) is a collection of data base information and user application software necessary to support a specific test (e.g. S0007) on an RTPS Set. User application software is developed and verified in processes described in section 4.4 of this document. The application software sources are stored in a Configuration Management (CM) Library. Application Software is extracted from the CM Library and executables are created and stored in a controlled area for subsequent inclusion in a TCID. There are three major steps required to construct a TCID to support a test. Step 1 is updating the DBSAFE database with Function Designator (FD) information. Step 2 is the Test Build process which extracts the FD information and the application software required to support the test and builds the necessary tables and files to support processing in the RTPS Test Set. The last step is the processes needed to load a TCID onto the test set and to initialize the set. Figure 4.1 depicts the data flow for a Test Configuration.

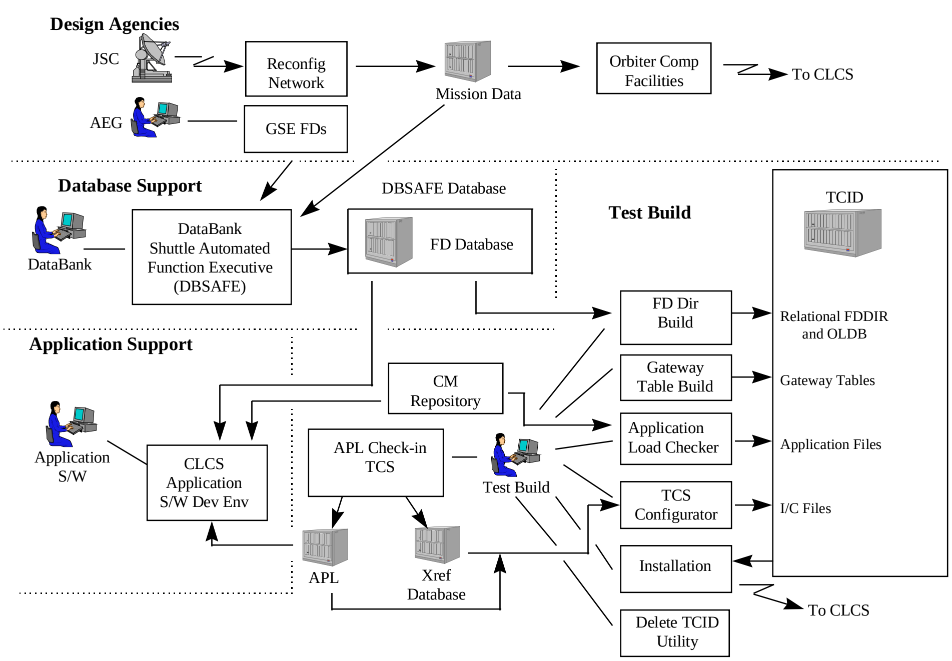

Figure 4.1 Test Configuration Data Flow

4.1.1 DBSAFE

The DBSAFE software provides the capability for the user to evaluate, incorporate, and track engineering changes to the FD Database. The FD Database is a relational database that contains all the FDs to monitor and control the vehicle, ground support equipment (GSE), Payloads, and the CLCS System. Shuttle and Payload FD information is defined on the Multi-file Shuttle Data Tapes (MFSDTs) at JSC. The MFSDT is sent from JSC to KSC via the Reconfiguration Network. Most GSE FDs are defined in KSC AEG (Automated Engineering Order Generator) System. Other FD information is received from various design agencies and input to the database by DataBank personnel. After the FD information is updated into the database, the FD data is available to support the CLCS Application Software Development Environment and the Test Build process.

4.1.2 Test Build

Test Build provides the capability to create, populate, and install the tables and files that comprise a TCID. Test Build extracts a subset of FD data required to support a specific test or set of tests (e.g. the FDs relating to the specific orbiter tail number being supported, the ground facilities being used, and the specific FDs for the payloads being launched) from DBSAFE for the specific CLCS TCID. The extracted data is loaded into Relational Database Management System (RDBMS) tables (FD Dir) uniquely created for each TCID. From the FD Directory, the Online DataBank (OLDB) and process control table files are created. Next, data is extracted from the FD Directory to build processing tables required by the Gateways to process end item commands and measurements. Then, the appropriate user application software files (End Item Managers, Data Fusion Files, Data Health Files, TCS Files, Dynamic Display Visualization Tool (DDVT / SL-GMS Displays) and etc.) are extracted and included into the TCID. The Test Build process installs the appropriate TCID files into the Test Build Repository Area on a server for subsequent installation of the TCID by OPSCM on the target CLCS Test Set.

4.1.3 Test Set Configuration and Start Up

Startup activities and procedures are performed in order to prepare a group of CLCS resources to support vehicle or GSE testing. The configuration of these resources involves the utilization of the set master, test set master, the SDC, network management, and other software tools and utilities. CLCS hardware is allocated, configured, and loaded as a test set comprised of a control group, gateway group, flow zone, and network segments required to support test operations.

Set management provides CLCS support personnel the ability to control CLCS resources. This interface provides access to configure hardware/software resources within a CLCS test set. It also provides methods to set hardware/software operations mode (e.g., test, redundant, spare). Access to the set management interface is restricted to the appropriate discipline (i.e., test set master, support operations).

4.1.3.1 Test Set Configuration

Prior to the test , the set master located in the COF allocates the required hardware resources based on the test set configuration file from SDC. A set master is initialized and retrieves the test set configuration file from SDC and initiates the configuration of the pre-allocated resources into a test set. Hardware configurations are checked and validated to the gateway interface. Software provides configuration information about pre-existing TCID(s), SCID(s) and operating system information residing within each hardware platform, overall resource sizing information, all network components, and resource allocation status. All configuration information is recorded to the SDC.

4.1.3.2 Test Set Load

After the test set is configured properly, it is loaded and monitored from the test set master. Utilizing the test set configuration file and information obtained from the test set configuration activity, software determines if the desired TCID, SCID, and operating system revision currently resides within the test set resources. If the desired software has not been loaded, or if it needs to be re-loaded, the pre-defined software residing within the SDC is loaded into the target platforms. Software monitors the progress of the load process, while the SDC loads the test set platforms and provides data integrity and verification mechanisms to insure proper platform load and configuration.

4.1.3.3 Test Set Initialization and Start Up

After all test set resources have been loaded, the test set master is re-initialized, and software that monitors the health and status of the Test Set resources, along with redundancy control software, is enabled and activated. All test set subsystems are then initialized to a non-operational state and tested for their operational readiness to support test operations. Upon successful operational readiness verification, the test set is placed into the operational state and acquisition and processing of data from the end item(s) is activated.

4.2 HARDWARE SUSTAINING PROCESS

The operational availability and performance levels of the CLCS hardware are affected by the specific maintenance and sustaining engineering processes used, and by the logistical support effort required to ensure those processes are effective. The maintenance process involves a three tiered approach to repair or replace hardware at the most cost effective level. The sustaining engineering process employs equipment upgrade and modification processes to maintain peak performance.

4.2.1 Hardware Development

Since CLCS is based primarily on COTS hardware, the need for hardware development is minimal. Any new development is performed much the same as it was in LPS, following established procedures and processes.

4.2.2 Hardware Maintenance

Hardware maintenance for CLCS includes the performance of reliability centered maintenance to retain system operability, and corrective or unscheduled maintenance as dictated by equipment malfunction. Hardware maintenance may be accomplished at the organizational, intermediate, and depot levels. Organizational level maintenance is performed in the on-line environment, while intermediate and depot level maintenance are performed in the off-line environment. The level of repair in each environment is determined by the CLCS Maintenance Plan.

4.2.2.1 Organizational Level Maintenance

Maintenance at the organizational level is generally limited to the periodic servicing of equipment through scheduled downtimes, troubleshooting to isolate failed assemblies, and the removal and replacement of Line Replaceable Units (LRUs). These maintenance actions also include in-place modifications, calibrations, line validations, and system reverification.

Organizational Maintenance relies on diagnostic tools, network health and statistics from network management, and operational data from the set master and test set masters. These data sources supply operational health, status and test result information to the maintenance monitor.

The maintenance emphasis at the organizational level is to return any failed hardware to an operational state as soon as possible in order to support test operations. A Vendor Support Center concept is used to meet this goal. In the vendor support center, a minimum set of equipment is located near critical on-line environments to provide a complement of LRUs which are always available for use as a functionally verified spare. These verified spares are immediately available for installation in the on-line environment. Vendor supplied spares and vendor expertise are available in the support center for all critical tests. For less-critical situations, replacement LRUs are available from other locations.

4.2.2.2 Intermediate Level Maintenance

Maintenance at the intermediate level is directed at the repair of LRUs removed from the on-line environment. Intermediate level maintenance includes troubleshooting to isolate failed LRUs to the sub-assembly level and the repair disposition of those assemblies. Intermediate level maintenance actions also include LRU modifications, off-line calibration, and LRU reverification.

Intermediate level maintenance relies on diagnostic tools, Automated Test Equipment (ATE) (for custom components only), and independent test systems to diagnose failures. The tools used to diagnose LRU failures are described in each system's maintenance plan.

The off-line maintenance area is the primary hardware disposition area for CLCS hardware, where off-line maintenance personnel manage the repair process. This is also where repaired hardware is verified to be operational and compatible with existing systems prior to assignment as serviceable spares. No LRU or system component is used in the on-line environment until verification has been performed.

The level of repair for CLCS hardware is documented in the CLCS Maintenance Plan. Return-to-vendor or repair-on-site decisions are based on the most cost effective method to maintain the target system, and include:

1. warranty considerations
2. maintenance agreements
3. proprietary components and/or documentation
4. test methods and requirements
5. revision level management
6. on-site resources (such as tools, test equipment and skills)

4.2.2.3 Depot Level Maintenance

Depot level maintenance is the repair or disposition of sub-assemblies at the component level. Generally, depot level maintenance is performed by the original equipment manufacturer or 3rd party maintenance vendors. Depot level maintenance of any CLCS custom hardware is performed at the off-line maintenance facility.

4.2.3 Supply Support

Supply Support is responsible for storage and issue of parts and material in support of CLCS operations and maintenance. Parts and materials include spare LRUs, piece parts, consumables, tools, test equipment, and general supplies. CLCS Material Service Centers (MSC) are also responsible for administrative duties as related to property transfers, equipment excessing, and RTV items. The majority of spare LRUs are COTS items and are maintained either by manufacturer warranty, extended warranty, or service agreement. Supply support provides delivery and equipment relocation that is consistent with and supports existing vendor maintenance agreements, thus reducing repair turnaround time and the requirement for additional spares.

CLCS Material Service Center (MSC) is strategically located to best support both on-line and off-line maintenance requirements. An MSC is located in the LCC in order to provide optimal support for critical functions in that facility. The MSC is where support of both on-line and off-line maintenance occurs. Additionally, the MSC supports remote CLCS areas including HMF, SSPF, as well as SAIL and DFRC as required. Spares are stored in those strategic areas as identified by Logistics engineering. Additional or overflow spares are located in the central warehouse facility.

CLCS will be monitored throughout its life cycle to ensure efficient and economical support is maintained. This monitoring includes the review of spares inventories for availability of components and suppliers, evaluation of the maintenance concept and repair philosophies established in the maintenance plan, and assessments of existing support postures when system modifications are proposed for CLCS.

4.3 SYSTEM SOFTWARE SUSTAINING PROCESS

System software provides the development, build, load and execution framework for operating a CLCS test set, executing user application software, executing simulations and performing SDC support functions. System software is a combination of COTS and CLCS-developed software that executes on top of COTS operating systems (UNIX, NT, VxWorks, etc.).

4.3.1 System Software Development

System software is developed and validated in the SDE and IDE. The CLCS system software development process considers current system functionality, user's needs and proposed operational concepts. Software is reviewed against the total system architecture. The review process considers the total software life-cycle including the sustaining phase.

4.3.2 System Build

The System Build process is performed within the SDC and creates the system software loads for individual RTPS subsystems. The system build product is a SCID, and is a collection of unique system software components, system tools, utilities, etc., that are required for RTPS subsystems. Upon completion of the system build process, the SCID is transferred to a repository within the SDC.

System build also defines and maintains the SCID Configuration Table. The SCID configuration table tracks all information pertaining to an SCID. Via a tool, CLCS users may name, list, add, modify, or delete both development and controlled build products within an SCID. CLCS users have the capability of placing both tested and untested software in the system build repository.

An SCID does not include the platform load (operating system). The OS load is built from a CM repository located in the SDC. However, each SCID will be associated with compatible platform loads.

4.4 APPLICATION SOFTWARE SUSTAINING PROCESS

The application software sustaining model uses an efficient process to enable safe and rapid support of user requirements. The Applications process utilizes a quality designed in philosophy. Each application developed component is associated with an appropriate level of test. The process: captures user application requirements in a consistent fashion, imports requirements into the design process, cross-references design to requirement, provides test plan identification (test plan verifies requirements are satisfied), develops code that matches real world components and provides the confidence that the delivered product has been appropriately tested. The Application sustaining process makes extensive use of COTS tools and industry best practices. To further enhance efficiency, rapid prototyping is used. Standards are used throughout the process to ensure consistent high quality products.

There are three elements within application that adhere to the standard sustaining process (the process is optimized for the unique needs of each). The three elements of applications software are:

1. Real-Time Control which provide the software products for the command, control and real-time monitoring of GSE, Vehicle, CLCS and facility components.
2. Data Analysis and Presentation (DAP) which provide the software products for the near real-time data reduction and analysis processes.
3. Simulation which provides the software products for Real-Time Control and DAP software debug and validation. Simulation also provides software products to allow training without using actual GSE, Vehicle or facility hardware.

4.4.1 Application Software Development

Application software is developed using a Desktop Development Environment (DDE), in the SDE and/or IDE. Application validation occurs in the IDE. Application software is developed to meet the needs of the user that are specified in application Functional Requirements Documents (FRDs). The FRD details the monitor, command/control and display processes required by the user community.

4.4.2 Test Build

The Test Build process is performed within the SDC and creates the test specific software loads used to control end items. The Test build product is a TCID, and is the association of an SCID along with the applications information that provide connectivity to end items. The Applications input to the TCID includes:

- Dynamic Displays: These displays provide information about the vehicle/GSE/CLCS components and request, initiate, and control both commands and automated sequences. Displays can provide tabular and graphical information of both hardware and software.
- End Item Managers (EIM): EIMs perform component control and provide the sequencing functionality to vehicle/GSE/CLCS devices. EIMs connect sequence control and the user interface (provided by dynamic displays) to function designators. RCL events cause the EIM to take appropriate safing (sequence) action. The command interlock (i.e., PCL) component is defined within the EIM (at the function designator level). PCL execution occurs regardless of EIM or command issuance method.
- Data Fusion: Fusion combines values of multiple inputs to derive a single output that can be used throughout CLCS. Algorithms, input parameters and priority for each fusion measurement are specified by the user prior to test build. Fusion allows the operator to work at higher levels of control.
- Data Health: This provides a mechanism for determining the health (i.e., validity, accessibility) of individual FDs. This health might include all data path elements of CLCS (e.g., HIM, gateway, etc.) as well as vehicle/GSE specific elements (e.g., power supplies, signal conditioners, MDMs, etc.). Health information is available to displays and other test applications (i.e., EIMs, data fusion).
- Test Control Supervisor (TCS): This provides a method to produce onboard General Purpose Computer (GPC) executed software checkout components used for turnaround operations. TCS supports activities that cannot be implemented via an EIM due to LDB throughput. TCS generated code is recognized by the GPC TCS executor.

Test build uses the DBSAFE data repository that associates end item addresses to unique names (referred to as Functions Designators) links the user defined applications to the FDs and provides output products that may be loaded on a test set for operational (or simulation) control. Upon completion of the Test build process, the TCID is transferred to a repository within the SDC. Individual components of a TCID can be updated (without an entire rebuild).

The TCID build process provides grouping of both tested and untested software components. Allowing only the deployment of tested, validated software into an operational environment.

5. ENVIRONMENTS

Various environments enable the CLCS system to function. The command and control environment details the CCWS functionality from a user's perspective. The safing environment provides components to control end items when failures occur. The development environment provides tools that support software development. The voice and video equipment are hardware components placed in various locations throughout the control rooms to enable voice communications for the checkout and launch team and to provide visibility into remote operations. The business environment provides the tools and capabilities to analyze data collected during vehicle, GSE, CLCS, and facility testing.

5.1 COMMAND AND CONTROL ENVIRONMENT

The command and control environment is the users' look and feel into the functions provided by the CCWS in the operational environment. Viewers are the user's window into the data that can be represented by the system. Control programs are those items that perform work to support user test requirements.

5.1.1 CCWS Human Computer Interface

The CCWS provides the user with a standard, consistent look and feel for all products, and is the same for all users. This standardization reduces training time and presents a universal view at the CCWS.

The CCWS display contains a fixed menu area that is always in view across the top and down the left side of the CCWS monitor. This area displays such data items as TCID, time, vehicle, top level status of links, data formats, stopwatch, console assignment, and other standard information universally required by the user community.

The fixed menu area also provides interfaces to general user interface controls (e.g., command entry, events, safing) application/system provided viewers, and other information available to users. The overall layout remains consistent for all users, even though specific details within the fixed menu area change depending on the test set and user class.

Both the systems and applications displays developed use standard methods (mouse control, colors, tool bars, etc.) defined in the global CLCS HCI guide. The primary CCWS monitor displays the fixed menu area, a user selected dynamic graphical display and perhaps a virtual safing panel that is always in view. The other CCWS monitor is used to display EIM, data, event, plot, potentially a secondary dynamic display, and message viewers. This segregation of functions ensures the primary graphical display is not obscured by "informational" viewers. Monitor layouts will evolve as the system is deployed.

Commands to end items via either mouse or keyboard are implemented in a manner, such that an inadvertent mouse hit or keyboard hit does not issue a command. The issuing of a command via the mouse provides a mechanism (e.g., double click, click-hold-move-release) to ensure that a single key depression (without moving the mouse) does not send a command. There are two different methods to issue a command from the keyboard. The first requires the operator to perform two keystrokes to issue a command (i.e., arm/execute). The second requires the operator to enable the capability to issue specific commands with a single keystroke. This enabler function essentially requires operator action in two segments. The enabler allows for the time critical keyboard control (e.g., safing) via a single keyboard keystroke only when invoked by the operator. The normal mode of operations is two step, with the use of the enabler function restricted to time critical items.

5.1.1.1 Command Entry

A command line is provided which allow the user to directly input and send a command request. Scrollable lists are also provided to allow input via "point and click" (versus command line typing). Syntax of commands entered through the command entry interface are checked at an appropriate level to assure only syntactically correct, range bounded commands are sent to end items. The command entry user interface is initiated through an interface on the fixed menu area.

The controllability provided by other user interfaces (e.g., set management, retrievals) is not duplicated within the command entry interface. Access to these types of interfaces are provided by a specialized GUI method only. The command entry interface provides a scripting capability where a series of commands can be stored in a file and be fed to the command entry interface for automatic execution. The scripting function is normally inhibited but can be allocated to a specific console by a console allocation agent.

5.1.1.2 System Browser

The System Browser provides a hierarchical insight into structural elements of the CLCS system. This integrated browser presents a comprehensive view of all aspects of the system (from the top down). The view, much like a directory, file, sub-file viewer, shows the relationship of end item managers down through End Item Components. Individual data elements (FD) attached to the EIMs and EICs are also displayed. The command assignment agent can alter real-time resource information from this browser.

Early development versions of CLCS provide a Data Browser in place of the system browser. The data browser provides the ability to scroll through or search the list of all data available in the test set.

5.1.1.3 FD Details

FD details provides information on specific data. For FD measurements or commands the viewer provides addressing, health, constraint, and use information. For fused data, the location (e.g., EIM/EIC, fusion component) where that data is computed is provided (i.e., fused data does not have a physical hardware address) along with health, constraint, and use information. FD details does not provide information that is embedded within the application space.

FD details provides the control mechanisms for authorized users to affect changes to the information about a data element. This control includes the ability to change value, alter constraint limits, affect health, etc.

5.1.1.4 Dynamic Display

The dynamic display provides multi-level view and control of CLCS, vehicle, GSE, and facility systems. Displays are developed to provide overall views of the system with further detailed screens available. The dynamic display is surrounded by the fixed menu area .

5.1.1.5 System Status

System status provides the capability to monitor both overall CLCS health and status, and detailed (subsystem) resource health and status. The graphical displays are selectable to the desired level of detail. Authorized users can affect system configuration changes through the System Status interface.

5.1.1.6 Constraint Messages

Constraint messages provides a scrollable list into triggered out-of-limit conditions. Authorized users can acknowledge or inhibit the response to constraint messages present on the message list. There are two types of constraints, those used by EIMs for controllability and those used for viewability. Controllability constraints may also have an associated viewability requirement. All constraint occurrences are recorded in the SDC (even if not viewed via the constraint message interface).

5.1.1.7 Simulation Control

Simulation control is only available when the test set is configured to support simulation testing. It allows users a one way (command only) access to the simulation system and the math model through the CCWS. The normal method for interfacing with the model is through the support workstation which provides both command and status from the model.

The CCWS interface provides a much needed “hook” from the CCWS to the model. This “hook” allows for the automation of test processes used by real-time control applications. Once a simulation connection has been established, commands can be sent to the simulation system. Test scripts use this interface, where applicable, to off-load often tedious and laborious manual validation processes.

5.1.2 Viewers

Viewers are used in CLCS to provide visibility into both the data and the processes in the system. Viewers do not provide the capability to issue/send commands to affect change to end items. Viewers are provided for most of the applications support tools and are accessed, at a minimum, through icons on the CCWS fixed menu area.

5.1.2.1 Data Monitor

The Data monitor provides a capability to display a number of elements in a cyclic fashion. This specialized data viewer displays the FD, nomenclature, present value and health in a scrollable list. Data can be easily added to and taken off the list.

5.1.2.2 End Item Manager (EIM)

The EIM viewer provides real-time insight into the processes controlled by end item managers. This viewer shows the state of the EIM from various viewpoints or levels of control. The viewer identifies the current state at each of the viewed levels. The EIM viewer is display only, with controllability occurring through the dynamic display.

5.1.2.3 Plot

The plot capability provides a multi-measurement graphical scrollable plot of data. The user can select measurements via the plot viewer, through the data viewer or via an action on dynamic displays. The plot capability also allows for a tabular view of data (digital patterns are best viewed in tables not graphs).

Historical data is available through the SDC interface (on the support workstation).

5.1.2.4 System Message

The system message viewer provides insight to CLCS applications and system generated messages. This viewer allows the user to scroll through messages at an appropriate level but is provided with default viewability settings, a subscription, based on the user class supported at the workstation. The user can change the subscription settings or view messages outside the subscription view without changing the subscription settings. When the console allocation agent adds or removes a user class to a CCWS, the subscription changes (the user can always select outside the default). When the user selects outside the default, a user class change does not alter the user based subscription.

Each CLCS component can generate messages. Messages are identified by the sender and categorized in three levels error, warning, or informational. Error messages are items that require immediate operator attention/intervention. Warning messages indicate a situation that requires attention or that is approaching an error condition. Informational messages provide useful operational information. Each message (within a category) is identified for publication to all in same test set, all in same user class, to the local CCWS, or to only the SDC. All messages are recorded.

5.1.3 Control Programs

Control programs are the applications delivered components that affect end items. End items are not only Shuttle and GSE , but also CLCS components. End item managers provide the bulk of the controllability, with supplemental support via the orbiter computational facility which supports the unique interface to the orbiter's GPCs. Support applications allow access of other CCWS deployed systems (notably AI/expert systems) to acquire and publish data.

5.1.3.1 End Item Manager

Command access is provided through interfaces on dynamic displays. Commands typically reach the end item manager that provides the automated controllability of vehicle, GSE, and facility items. End item managers receive input from GUIs, or the next higher level EIM (providing a well-encapsulated control methodology). At the lowest level of automated control are end item components which are delegated the responsibility to manage a particular device. The end item control concept allows the EIM/EIC to contain the domain operational knowledge (i.e., how to control, what to report, etc.) about the item. The structure of EIMs allows for significant reusability at each level. EIMs are created via the EIM editor and viewed through the EIM viewer.

EIMs also provide a health status to the system. EIM health is monitored by system integrity and is available for display to the user. A monitor function exists to track the software state (e.g., active, error, terminated) and a control capability also exists to allow the orderly shut down of EIM processes.

5.1.3.2 Support Applications

CLCS provides a control interface which enables AI and/or expert system products (developed external to the EIM) to function within the CCWS. While these support programs do not directly command vehicle/GSE/CLCS end items, they can provide a capability to publish data. The data publish function may require the broadcast of pseudo function designators. Support applications may also provide the capability (in follow-on CLCS projects) to affect the computation of data health.

5.1.3.3 Orbiter Computational Facility

The Orbiter Computational Facility (OCF) provides an interface from the CCWS and real-time control applications to the GPC(s). OCF supports both an operational capability and an off-line function. Operationally, OCF supports activities like Mass Memory Unit Load/Dump/Compare and similar operations for other electronic units. RTC application connectivity to OCF is provided to allow the applications control of these load/dump and compare type activities. Data files, tapes, and listings to support the operational activities are generated by OCF off-line.

5.2 SAFING ENVIRONMENT

Currently in CCMS there are four different types of safing in use in the control rooms: 1) Launch Data Bus (LDB) safing; 2) GSE hardwire safing; 3) program safing initiated through programmable function panels (PFP); and 4) both prerequisite and reactive control logic. Provisions must be made to incorporate the functionality of each type of current safing in CLCS. New safing systems to support CLCS must be simple, reliable, and support the "generic console" concept. The generic console concept means that any console can be configured to support any engineering system including the appropriate safing panel. Safing panels are made generic through the use of patchable programmable interfaces between the consoles and the end items. In line with the generic console concept, safing will be identified as either independent safing or applications-provided safing. Independent safing will include vehicle and GSE safing. Applications provided safing will include control logic and program safing.

5.2.1 Independent Safing System

Independent safing will be used to affect safing of critical vehicle and GSE functions without the use of applications software and with maximum independence from CLCS. This is equivalent to the hardwire safing system provided in CCMS. The independent safing system requires a self-test feature to ensure that the console safing panel is correctly configured to the associated end item.

5.2.1.1 Vehicle Safing

Vehicle safing will be the equivalent of CCMS LDB safing and is required for CLCS to protect against command server and command path failures. This safing will be used separately from other types of safing but incorporated into the overall CLCS software structure.

5.2.1.2 GSE Safing

In CCMS, the failure of LPS could cause a loss of critical GSE or vehicle control capability. In the CLCS environment, GSE safing panels in the OCRs are provided to ensure a backup control system for emergency safing and securing if a significant loss of CLCS capability occurs. GSE safing provides appropriate emergency responses and safing actions through a system wholly independent of CLCS. This system will also have a mechanism for continuously verifying its integrity. Sufficient GSE safing links will be provided to support both integrated and non-integrated processing from the OCRs.

GSE safing will be implemented in a manner which allows consoles to remain generic. There is no plan to include the safing system hardware running from the LCC patch racks to the site in CLCS. The power for the GSE safing system is separate from CLCS.

5.2.2 Applications Provided Safing

Application safing processes are provided within CLCS real-time applications software to prevent the issuance of unsafe commands and respond to requests to safe end items. Control logic is provided to automatically execute when certain command and measurement data changes. Program safing, which can be user invoked to safe systems, is also provided.

The CCWS use has direct and unambiguous access to critical control functions (e.g., GLS cut-off, emergency power-down, hydraulics power down, etc.) which are implemented in real-time control software. Direct access allows the coding of Operation and Maintenance Instruction (OMI) emergency safing sections with a definitive description for these activities which can be implemented in a minimal amount of time. The software programmable safing control does not replace the independent safing system since it continues to rely upon CLCS resources to operate. This is roughly equivalent to the safing functions (stop flow, revert, etc.) invoked by the PFP in certain engineering disciplines in CCMS.

5.2.2.1 Control Logic

Two automated methods of application safety are provided by CLCS. Prerequisite Control Logic (PCL) precludes the issuance of unsafe commands to end items. This essentially acts as a command interlock. Reactive Control Logic (RCL) responds to off nominal conditions by sending commands to secure systems.

PCL is a user-defined set of logic associated with one or more stimulus type function designators. PCL is a function of function designator values, data health criteria, and the value of the initiating stimulus FD (e.g., ON or OFF). The logic within PCL determines if it is safe to issue the initiating stimulus. When an FD has an associated PCL, it is executed at the FD level regardless of the command input method (i.e., for every EIM issue or command entry issue). PCL can be inhibited or overridden if the user is able to determine, through alternate means, that it is safe to issue the initiating stimulus. PCL can also be inhibited by/within an EIM, when test requirements dictate.

RCL is a user-defined set of logic associated with one or more function designators. RCL is a function of function designator values, and data health criteria. The logic within RCL reacts to predefined off-nominal conditions resulting in the issuance of stimulus FDs to obtain a safe configuration. Because of the timing required, RCL is directly connected to the required input data (i.e., RCL does not use fused data as input). RCL can be inhibited or overridden if the user is able to determine, through alternate means, that it is safe to disable the function. RCL can also be inhibited by/within an EIM, when test requirements dictate.

5.2.2.2 Program Safing

Program safing is provided by applications to secure systems in an orderly, methodical method. Program safing may be initiated via dynamic display input (e.g., action/cursor block, virtual safing panel input) or by sequence logic provided in an EIM. Program safing differs from control logic, in the method the action is invoked. Control logic occurs at the FD level, while program safing occurs at the sequence level. Program safing may be called as the result of an RCL “hit”. Examples of program safing include: revert, GLS safing, emergency power down, etc.

5.3 BUSINESS ENVIRONMENT

Documentation takes on many forms including written text, strip chart recorder pen plots, electrical and mechanical/fluids engineering drawings, pictures and other graphics. All of these forms of documentation and reference material are utilized by console operators and maintainers to perform their various tasks during daily processing and launch operations. In fact much of the engineer’s time at the console is occupied with communications and the mechanics of the test process. By providing access to procedures, reference documentation, office computer tools (e.g. E-mail, fax, scheduling, word processing, data base, and data analysis), and other support systems, much of the time spent communicating or gathering and analyzing information can be saved.

In the countdown environment today, when a problem occurs, communicating a problem’s description to the interested decision making parties takes significant time and is, at times, error prone. Computer-based tools and strategies can help alleviate this class of problems by providing the same display capability to all users and by providing, as an example, collaborative tools like a computer “white board” to visually annotate and discuss data via the business computer systems via the SWS.

The ability for logical groups of console operators (e.g., an engineering discipline) to access and manipulate sets of group related data will also provide for a more business integral environment. As an example, group E-mail accounts or group engineering log database access help provide for rapid categorization and dissemination of routine engineering tasks.

CLCS acknowledges the need for isolated (from RTPS) computer based assets and infrastructure to support the processing, operations, sustaining and maintenance users within CLCS test sets. It is also acknowledged that this capability is needed to support the various business and analysis processes currently performed either manually or with the aid of external legacy systems. Efficiencies can be gained by bringing these computer based tools into the control rooms to users.

In general, two basic goals exist: 1) provide, as a minimum, the functional equivalent of the general office computer tool suite, including access to legacy business systems (IWCS, SCAN, USAGO-LAN, SPDMS, GPSS etc.); and 2) provide services for CLCS/SDC specific capabilities including:

- SDS data display
- Near real-time data archival and retrieval/presentation
- Data analysis & user defined processing

- Network connectivity or platforms and system software services for user/external customer advisory systems

The business systems provide assets to either execute or access, at the support workstation, functions supporting processing and launch activities provided by both CLCS hosted and non-CLCS hosted applications. To provide sufficient flexibility and lower costs, a mix of client/server, X-Server and direct application execution shall be provided on the support workstation.

Systems either executed within the CLCS workstation/server environment or accessed externally can be classified into three basic categories: 1) support services, 2) business systems, or 3) advisory systems.

Support services are those functions which provide CLCS operations-unique functions. Examples include applications necessary to access, retrieve, and display historical SDC data, non-real-time plot and presentation software, and an OTV user interface. This category also includes system services software (API's) to allow applications to access, buffer, and manipulate real-time data packets; make logical connections to the SDC for data recording and archival retrieval functions; and for print and display functions.

Business systems provide process support to engineers, technicians, test-conductors, and managers in processing and launching the Space Shuttle. Business systems help document and track many aspects of the processing "process". This can include authoring and performing Work Authorizing Documents (WAD) to perform tasks including planned test procedures, problem identification and troubleshooting, unplanned test procedures, task scheduling and execution tracking (Shop Floor Control-SFC), Test Requirements Tracking (OMRSD), Engineering Drawing Review and Release, etc. These various legacy systems are implemented on a variety of computer platforms and networks and are located at various locations both on and off site. The support workstation provides the hardware, network connectivity, operating system platform, and infrastructure necessary to perform these office functions. CLCS provides interfaces to the currently documented business applications used at KSC as listed in Appendix B.

Advisory systems are a set of user developed applications which include such things as APU Neural Network, Propulsion System Advisor (PSA), Shuttle Connector Analysis Network (SCAN), LOX Pump Vibration Digital Signal Processing Analyzer. Execution of advisory system applications can be supported in any of three ways: 1) on a CLCS provided server; 2) On a customer/user supplied platform with CLCS providing network connectivity, power and environmental needs; or 3) direct execution on the support workstation.

The convenient access to advisory systems from a support workstation will allow for a more thorough and timely resolution to anomalies where data analysis is required. Access to near-real-time SDC data retrievals, historical data retrievals and advisory system's analysis information will significantly reduce the time a given processing task takes.

5.4 DEVELOPMENT ENVIRONMENT

The development environment provides the tools and editors to create and maintain the software provided by CLCS. The section describes the applications development environment, the tools supporting real-time control applications and a conceptual description of the application.

5.4.1 Applications

Application software is deployed in the SDE and IDE for user test, validation and acceptance. As applications are developed, the ability for rapid turnaround of the development product is provided. CLCS provides a desktop environment which allows the applications developer to work efficiently with CLCS provided tools (COTS when available) to develop products. The DDE provides the ability for the user to make additions to the DDE provided environment, without incurring the organizational processing overhead. The DDE provides:

1. The ability to add to a desktop copy of the data repository, allowing the user to make changes and debug well ahead of a TCID build
2. The ability to execute test scripts to debug product output
3. The ability to connect to simulations to test developed applications (workstation resident in the DDE)
4. The ability to make rapid turnaround of code

The SDE and IDE also provide the application user the ability to quickly turnaround products. Because of the TCID information required, the user flexibility to augment the data repository is not supported (item 1 above). Rapid turnaround and testing is provided.

5.4.2 Applications Support Tools

A significant portion of the CLCS development effort is the creation and maintenance of programs that support test operations. CLCS provides a suite of tools to enable the rapid development, and deployment of these operational programs (generically referred to as applications). Configuration management is provided to ensure traceability (revision/change control) of deployed products. Typically, applications support tools are used in an office environment (unique real-time support requirements are identified). The following is not all inclusive and will evolve as the system evolves.

For each of the development environment functions, the user can create, edit, and view the associated data. The capability to create temporary FDs to support development is provided (in the DDE). Final FDs, however, must be provided by the DBSAFE repository.

5.4.2.1 FD Database

Mechanisms to allow the creation, modification and deletion of FD’s (all FD types) are provided. The FD database houses such information as data nomenclature, channelization, scaling, etc. The FD database tool supports rapid creation, edit, and delete processes.

5.4.2.2 End Item Manager

A tool set to support the functions required for End Item Management is provided. The tool set provides methods to encapsulate the processes used by the various end items. The processes could include reactive and prerequisite logic , control processes (sequencing), and anomaly notification. The EIM tool set contains mechanisms for altering the data set used as input (or output) to the end item, manipulating the sequencing function and defining the interfaces to the end item. The EIM tool set provides for hierarchical levels of EIMs.

The EIM tool provides the capability for User control of the process. This control includes the capability for Stop, Step, Resume and Goto (branch to a specified location). This control is usually restricted in an operational environment (e.g., requires permission to use) and is always available in the debug environment.

5.4.2.3 Data Fusion

A tool set to allow the creation of “fused” measurements is provided. The fusion mechanism provides a capability to gather various inputs and create a “fused” or unified output. The fusion algorithm is created and tested prior to deployment in an operational environment. Any change that affects the computational method of fusion measurement (in real-time) must be traceable. In order for the fused measurement to become available to the user, an update of the FD database (and TCID build) is required.

5.4.2.4 Data Health

A tool set is provided to define a deterministic set of parameters that define whether data is "healthy". The health tool provides methods to encapsulate the logic required to determine when data is valid (i.e., is providing usable data). Data refers not only to measurements, but also to commands. Data health typically uses the following deterministic inputs: network status; gateway status; HIM status (for GSE data); operating mode (for LDB and certain GSE command types); data format (for vehicle measurements); and others (the list is not all inclusive). User input is also available to mark measurements as unusable.

5.4.2.5 Display Development

A tool set is provided to allow the creation, modification and deletion of display programs viewed by CLCS users in an operational and debug environment. The tool set does not require a labor intensive process to update display parameters. The display tool (and the system) provides the ability to create a single display that can operate in "monitor-only" mode and a commandable mode. The display tool allows for display deployment with both modes while requiring only one user validation. The goal is to develop a single display that can be viewed both in the OCR on a CCWS and on the SWS, eliminating dual maintenance. The display tool provides the capability to use a set of defined screen element attributes (e.g., in range, off scale low/high, outside OMRSD/LCC limits) to assign colors. The tool also has the ability to provide internal logic to determine color regardless of the input attribute.

5.4.2.6 Test Control Sequence

A method is available in CLCS to support the development and deployment of Test Control Supervisor (TCS) sequences that are used for ground turnaround activities. TCS sequences are used by the General Purpose Computers (GPCs) to perform activities (e.g., time critical processes, back-up safing) that are not implementable by RTC applications due to Launch Data Bus (LDB) timing constraints. Application sequencing functions (independent of TCS) are supported by the EIM tool.

5.4.3 Application Summary

CLCS applications are comprised of two major components: Dynamic Display and Real-Time Control Automation. Displays are relatively 'dumb' processes that provide information to the user and accept user input (i.e., commands). The end item control power occurs within the automation process.

5.4.3.1 Dynamic Display

Dynamic displays are accessed through a standard task bar. The task bar lists all the displays available to the test set. Upon selection, the appropriate display is activated. Applications provide the interfaces to the task bar, the logic that executes within the task bar and the drivers that connect the task bar to the Dynamic Display tool. Dynamic Displays are developed using common repositories quickening development time and assuring display consistency. Dynamic Displays interface through a broker to RTC automation components. A user (i.e., the CCWS) has control for only those items that have been authorized.

5.4.3.2 RTC Automation

The automation component is comprised of a central control component, continuous monitor processes and test unique sequencing. The control component monitors system status and activates/deactivates monitor programs. The control component also receives requests from Dynamic Displays (and other components) to enable test sequences. Automation process fault response logic is also housed within the centralized control element. Continuous monitor processes gather end item data, produce summary information (the status of the end item), provide constraint control and event response (as required), and support the sequencing function. Monitor processes provide the 'higher level' control of end items (e.g., activate power supply 123 or open valve complex A01). Sequencing provides the complex control of end items (via the continuous processes) to affect system checkout. Sequencing provides status to the operator via messaging and user prompt interactions. Sequencing makes use of common constructs such as resume, hold, continue and secure.

Three support processes are provided: Data Fusion, Data Health and Display Attribute. The fusion process, which gathers sensor data to produce derived sensors, runs continuously at test set initialization (unlike automation monitor processes). This derived sensor data is available to all. Applications deliver to Test Build a definition of the fusion processes required. Data Health provides applications information data’s usability. Applications (and/or the user) may override the computation of health. A deterministic set of algorithms are produced during the Test Build process. The health process runs continuously after set initialization. Display Attributes are provided by monitor processes and/or sequences. The attribute logic provides system wide commonality when the element is incorporated into a dynamic display. The use of data health and the automation continuous monitor processes assure data is properly ‘colored’ on displays. When the monitor process is inactive, the data path health is bad. When the processes or sequences are active, the required limits are used.

5.5 WORKSTATION INTERFACE ENVIRONMENT

CLCS users have to interface with multiple networks from their console during test activities. These interfaces include keyboards, pointing devices, monitors, and peripheral devices. Implementation of these interfaces is done in such a way as to ensure that the CCWS is clearly delineated from the support workstation. This delineation is required to enable the users to have access to the broad range of BASIS services without degrading the command and control system’s performance or security. Any design used to support CLCS also includes an Electro-Static Device (ESD) protection system for all user interfaces.

5.5.1 Keyboards

There are two keyboards per console: a CCWS keyboard and a support workstation keyboard. In order to completely separate access to the command and business networks, CLCS provides keyboards for both networks. The CCWS keyboard will be capable of providing complete control of user test applications displayed on 2 monitors. Keyboard keys provide control for cursor movement on critical command displays. Specific functionality of each monitor in the CCWS minimizes navigation between screens using the keyboard. The CCWS keyboard is uniquely identified so as to distinguish it from the support workstation keyboard.

5.5.2 Pointing Devices

Separate pointing devices are required for both the CCWS and the support workstation. The pointing device will be able to move between the two monitors attached to the CCWS CPU. In addition, the pointing device is placed on the console in such a way as to preclude “losing” the device during execution of a test.

5.5.3 Monitors

Monitors are located in SE consoles, TC consoles, and support modules in varying configurations. Each SE console contains monitors for the CCWS, the SWS, and OTV. The CCWS drives two monitors combined into a “virtual” desktop where a single pointing device can move between the monitors seamlessly. Certain displays are restricted to being on the “primary” CCWS monitor, while others can be displayed on either monitor. Users view business services through a single monitor driven by the SWS. The SWS drives a single monitor when in an SE console, or a single 17-inch monitor when installed in a TC console. Workstations installed on a support module can drive any size monitor, although usually it is a 20-inch flat screen.

5.5.4 Peripheral Devices

Peripheral devices include printers, scanners, facsimile machines, copiers, and strip chart recorders. These devices are deployed throughout the OCRs in the support modules and shared I/O areas. Support modules contain an assortment of black and white printers, color printers, and combination fax/scanner/copier/printers. The shared I/O areas contain an assortment of color scanners, fax machines, high speed black and white printers, photo quality color printers, high speed copy machines, and strip chart recorders.

5.6 VOICE AND VIDEO ENVIRONMENT

The existing OIS-D and RF OIS systems are legacy equipment and continue to be used by CLCS. The OTV system is currently undergoing a major upgrade outside the auspices of CLCS. A coordinated effort is occurring between the OTV and CLCS projects.

5.6.1 Operational Intercommunication System

OIS control is not integrated into CLCS and existing OIS resources used in CCMS are used in CLCS consoles. Space has been provided in the console layout to accommodate this OIS equipment.

5.6.2 Telephones

Each SE console position is equipped with a trim-line (i.e., small footprint) two-line telephone. A variety of standard calling features (i.e., conference calls, etc.) are provided. Each TC console position requires a single multi-line phone. SE support modules are grouped in clusters of four. Each cluster of four is equipped with a single 2 line phone. Support modules located in the OMR/OSR areas require a single 2 line phone each. In addition, replacement of the existing network of point-to-point phones in the control room is required.

5.6.3 Operational Television

In parallel with CLCS development, the OTV system is being updated and redesigned. OTV is not fully integrated into CLCS, rather it is isolated from RTPS control system failures. OTV provides video surveillance of Shuttle processing activities as defined in the set of OTV requirements documents. It provides network and network connectivity to OCR console positions to support user control capability. It provides capability to select video input to video output at each respective console per video view. OTV will be user configurable through a graphical interface on the support workstations based on user permissions. Each console command position is capable of displaying two camera views.

6. OPERATIONAL SCENARIOS

This Operations Scenario section describes how CLCS will be used in two categories of Space Shuttle processing: 1) Integrated vehicle testing including launch; and 2) non-integrated multi-flow testing. This section is not intended to account for all possible scenarios for using CLCS, but to depict in a general sense how primary users of CLCS will interact with the fully deployed and implemented system.

These scenarios begin at the point when the OCRs have been configured by the set and test set master, including loading and initializing the test set equipment with software. Software has already been developed in a configuration controlled software production facility, and has been promoted to a configuration controlled server. Test set components have been loaded from the configuration managed system. The test set master has enabled command authority for a predetermined console command configuration for each of the OCRs.

6.1 INTEGRATED VEHICLE/LAUNCH ENVIRONMENT

The most comprehensive activity at KSC is launch, therefore, more CLCS resources are used during this test than at any other time. Maximum redundancy in common equipment and network components is needed for safe operations. The prime OCR and common equipment associated with the launch test set are dedicated from the time the vehicle becomes integrated through launch. Common equipment supporting the launch test set is also dedicated solely to that test. Common equipment must be fail-operational and command and control workstations (CCWS) fail-safe.

A system engineer arrives at their console for integrated testing or launch and notifies the test conductor on the OIS system that he is ready to perform his portion of the test. The engineer activates the system applications software needed to perform their systems functional checkout. On the support workstation the engineer accesses the test procedure being run. He can also access reference material and the World Wide Web to view system schematics if needed in support of his test. The engineer configures OTV through a graphical interface on the support workstation.

If the system engineer also happens to be working a hazardous portion of the test, he will need to verify that the correct safing panel is configured for his console. This panel will provide a backup capability to safe his associated GSE. The panel is versatile and can be configured for any engineering discipline. The safing self-test feature ensures that the safing panels are configured correctly to their designated end item.

The engineer is now ready to command his system. The application display selected shows a graphical depiction of the system or process. From this display he can select, for example, a desired component or value and, with a click of a mouse, send commands to his system or view constraints, fusion parameters, and real time plot capabilities from the CCWS. The system has provisions to prevent inadvertent commanding.

Because this is launch day, system specialist engineers observe and consult on the test from a support module located behind the system engineer. They have access to the business information network and can assist the system engineer with data analysis and retrievals and communicate with management and support organizations. The OCR is designed to facilitate the consoles being organized in logical groupings (e.g. data systems, fluid systems, electrical systems, etc.) to support collaboration and conferencing by the team. The engineers can communicate via OIS for formal call outs, but have the ability to conference, if the need arises, due to their close proximity.

Test directors and test conductors support integrated testing and launch from specialized consoles differing from system consoles. These positions require less data viewing space and more space for legacy systems like expanded OIS, additional phones, Astronaut Communications panels, Area Warning System panels, etc.

For integrated testing, the prime room (either OCR-1 or OCR-2) is configured as stated above for testing. In the launch environment, in addition to the prime control room, another OCR is configured to support engineering management's and system specialists' participation in the test. This configured OCR is termed the Engineering Management Room (EMR).

Engineers and system specialists located in the EMR for launch will be participating in the test from identical consoles and support modules to those in the prime control room, however these consoles will not have the CCWS enabled. These personnel will have access to all the data and displays being used in the prime OCR including those used in the CCWS, but for monitoring only. Although there will be no command authority and no active safing panels, all other capability in the EMR remains the same as the prime OCR.

The mission management team and center management and VIPs will be participating in launch activities from the OMR and OSR, respectively. These rooms are in the prime OCR. Each area is configured with specialized support modules which house support workstations, phones, and OIS. Large wall mounted OTV monitors are positioned around each area to allow clear viewing of selected OTV displays by all persons in the room.

Off-center users such as JSC MER and the HOSC at MSFC will have access to the CLCS Shuttle Data Stream.

6.2 NON INTEGRATED/MULTI-FLOW ENVIRONMENT

The majority of the time spent in the OCRs supports non-integrated testing, essentially the day-to-day activities at KSC. Since there is the possibility of three non-integrated vehicles and one integrated vehicle being processed at the same time, it is necessary to process two or more non-integrated vehicles and their associated GSE out of a single control room. From landing through OPF processing, orbiter testing is accomplished in a flow zone environment. Any of the three control rooms can be configured with multiple TCID loads. The room layouts are symmetrical in nature to clearly delineate the flow zones. Visual clues such as signs and color coding will also aid the users in orienting themselves with the proper flow zone for their testing. All CCWS displays clearly show the vehicle, test site, and TCID being supported. As a vehicle nears completion of its non-integrated flow, it and its associated GSE would typically be relocated from a flow zone environment to a prime OCR in preparation for the integrated flow and launch. It is intended that the vehicles migrate through the OCRs in a standard progression so as to minimize the need to reconfigure test sets and flow zones.

In this environment, an engineer would arrive in the OCR and report to the TC on station to be assigned to a console in the correct flow zone. Once at his console, the engineer reports on OIS. As with integrated testing, he activates his applications software, accesses the test procedure needed, verifies other reference material is available if needed, and configures OTV through a graphical interface on the support workstation. Engineers working hazardous operations also need to verify the proper safing panel is loaded and configured for their system.

Test operations are carried out by users from the SE console. Additional personnel can be located at the support module to assist the engineer in his assigned test. Consoles will be configured to allow for logical groupings whenever possible. The configurations of the flow zones will also be maintained from day to day where practicable so that engineers will be moved around as little as possible.

For powered vehicle testing, orbiter power up and monitoring will be able to be accomplished from a single console. A single engineer will be capable of controlling, safing, and powering up/down an orbiter. This provides for the maximum efficiency of hardware and personnel resources during power on testing. It is intended that advancements in application software and displays will allow significant consolidation in day-to-day multi-flow processing.

6.3 SIMULATION ENVIRONMENT

CLCS allows changes in the way simulation data is broadcast through the system. There are five operational scenarios for simulations. Single system simulation can be performed from the desk top in an office environment. Debug of monitor application and display can take place on a SDE or IDE set using playback data from SDC. Smaller multi-system simulations and software debug can be run from an IDE or SDE without requiring link support. Software validation can take place in the IDE or section of an OCR using full link support. With the added flexibility offered by CLCS, integrated simulation can take place in an OCR and sections of another OCR for management support.

	Local Model	Network Simulation	Simulation Gateway	Link Level Simulation w/ real G/W
Office	Initial debug	Initial debug		
SDE	Initial debug	Initial debug	Functional debug	?
IDE			Functional debug	Verification
OCR			?	Team training, S/W validation, set verification.

In the office environment the developer will have access to a set of development tools and a limited runtime environment. This runtime environment will allow them to interact over the network with current models or to provide limited local simulation. This will require little coordination by the developer to gain resources. In addition special development tools will be provided to allow for modification to the runtime environment in real-time to permit quick turn around initial debug of application code.

A developer or user schedules time on an IDE or SDE to test out display and monitor programs. After loading the set, previous playback data are requested to checkout new applications or help correct problems that were caused by the recorded data events.

An initial software debug session is scheduled by a developer or user. The required equipment to build a test set is allocated. A network simulator to the SGOS models is connected to the set. This will allow the developer or users to perform most functional testing on the application. The developer or users will have control of the model as well as their application from their workstation position The simulation system will also support individual system training by providing the capability to load up either a single system or integrated model in a standalone training scenario.

To validate application software the developer and the user will schedule an IDE or portion of an operational set. The IDE is configured the same as any other operational set. The set is connected to a set of link simulators. Actual operational tests and special test cases are run on the applications.

To perform a full application software test or full team training, an OCR will be scheduled. Full link support will be provided. The applications are controlled from the operational consoles. The model performance and insertion of faults is supported from support workstations. The simulation system will support Launch Countdown Simulation, Cryogenic Loading Simulation, and Hypergolic Loading Simulation training.

Appendix A Current Advisory System Interfaces

The following table documents current “advisory” systems and a suggested implementation method:

System	Existing Mode	Suggested Mode	Comments
Shop Floor-SPDMS II Access for NTD/OTC’s	TN3270 Terminal Access Via PC/Token Ring LAN.	Support Workstation 3270 Terminal Access	This capability will be provided for all BASIS workstations/users.
SSME Avionics and Advisory System	PC’s at C11/C12 LON connected	Support Workstation WEB and User Data analysis Software will satisfy this requirement.	It is expected that the support workstation, being an office standard windows95/NT capable workstation will satisfy these user requirements. Some user specific S/W (e.g. Rocketdyne PC-Plot) may be provided for the BASIS SW Load (local application execution).
IWCS functions in Control Rooms	IWCS Workstation (Token Ring connectivity) with TN3270 and WPSS Software.	Support Workstation with TN3270 Terminal Emulation and WAVE S/W Suite.	The largest task for the process engineer at a control room console is to run his/her procedure (OMI) and troubleshoot problems (IPR/PR work). The WAVE S/W suite allows for OMI Viewing, IPR/PR authoring and dispositioning. It is absolutely necessary that the BASIS support workstation be able to perform these tasks, as is done today, off line in the office. (WAVE is replacing the existing proprietary WPSS system)
PC-GOAL	DOS based custom applications on low cost PC’s, displaying certified real-time data broadcast (SDS) on the LON and Bridged SODN.	Migrate/transition the SDS to the CLCS Data Stream. Utilize Client/Server JAVA based deployment mechanism (J-GOAL).	The SDS also serves external and off site customers. Deployment by means of a standard front end (WEB Browser) and client/server method will have less impact to all users. Note: this is somewhat in conflict of the goal to develop and maintain only ONE set of real-time data displays in CLCS. Investigate the possibility of auto-generating J-GOAL displays from certified SL Displays should be accomplished.
User Laptop’s	User Supplied Laptops and user CM’d S/W.	Provide Isolateable BASIS Network Connections at	Connectivity to the BIN network will satisfy most of

System	Existing Mode	Suggested Mode	Comments
	Some require LON connectivity for TCP/IP based external access.	each Support module. CLCS to provide Port (Hub), Proxy and Firewall isolation.	these needs. The standard BASIS S/W (e.g. Browser, Access Database, Word Processor, etc.) will also satisfy this need and likely reduce the need for Laptop's or portable computers.
C-12 DPS Launch Commit Criteria Expert System	SUN workstation CLIPS rule-based application.	Functionality will be incorporated into CLCS RTPS Application S/W. Do not port or re-host.	Although this is the only SDS based application which decodes/processes flight element Digital Processing System telemetry (not available in a PC-GOAL display), no sufficient USER support for this system has been identified.
Backup HGDS Terminal's, HUMS	DUMB ASCII based terminals connected via dedicated comm lines to HGDS systems located in the mobile launchers. Receive portion of the full duplex asynchronous comm link drives display-only terminals in the management (#2) control room.	HGDS Survivability is addressing this issue (Short Term) by developing a PC based replacement for the Dumb Terminals. Current proposal involves having the new PC format and send BU-HGDS data packets to the CLCS consolidated Gateway for incorporation into the SDS. This will allow for use of PC-GOAL displays	Long Term, the Hazardous Warning Systems will be combined into a new system (HGDS-2000). HGDS, BU-HGDS and HUMS will be incorporated into the RTPS with a dedicated Gateway and EIM Applications Software. This is expected to take place near the end of the CLCS project development. Currently, the CLCS Application re-engineering effort will pick up existing CCMS command and data interface capability for these systems. Potential exists for X-Term sessions into the HUMS SGI Server Set (HUMS Local Ethernet would need to be bridged to the BASIS network) if firing room (BIN/BASIS) access is needed.
Flare Stack Monitor	Laptop with vendor supplied PLA control and monitor software connected via a dedicated comm line to the flare stack PLA. Basic (limited) flare stack visibility is provided by the PLA to CCMS HIMS. Laptop is provided to give additional control and	This "single string" system is not command critical and could be executed from a BASIS workstation. This, however, deviates from the "no commanding" rule for BIN related applications. Use the DE/User supplied GSE Laptop on a support module with additional comm port wiring.	To satisfy this need, either the RTPS will have to have a unique gateway and/or application server interface, OR a uniquely configured BASIS type of Support Workstation would be needed. Probably not worth the expense to incorporate into the RTPS due to the vendor plug and play software issues involved with facility process

System	Existing Mode	Suggested Mode	Comments
	display.		control implementations. Issue: No apparent means to get laptop collected data into the SDS/SDC. A CCS type of application, but related to CRYO operations.
MARRS	NASA/USAF Safety Application and mainframe (USAF-VAX) access applications via a dedicated network connection. Utilizes weather information to predict toxic plume area and motion for hazardous operations.	Do Not Port-re-host.	Issues: Currently executes on a Tecktronics workstation and over relatively secure network connections to the USAF mainframe. Uncertain if the applications can be made to run on a support workstation or ported to an SDC application server. Also, the USAF have unique networking interface requirements. (213)
Propulsion System Advisor (PSA)	Currently, a SUN based application which is operationally used in FR #2 AND the data review room. It's undergoing DCR certification and will be utilized in prime control rooms. Provides mass/flow/leak calculations and predictions and provides historical v real-time plotting and analysis capabilities.	It is not deemed practical to port or re-code this system into the RTPS. Optionally some re-coding may be needed for full X-Windows/MOTIF compliance. CLCS will provide for a minimum of 2 SUN workstation BASIS Network connections for this application anticipating X-connections from a BASIS Support Workstation.	CLCS needs to assess the resources needed to re-code or port this application to a CLCS provided (e.g. DEC Alpha) applications server. It is desirable that this application's display be available to a few others (management) during terminal countdown. User is Process Engineering Cryo/Fluids.
Propulsion Advisory Tool	Currently being re-hosted to a SDC DEC Alpha Server. Runs a G2 based application for mass/flow and leak calculations.	This system is currently being funded by CLCS to be developed for the SDC advanced Applications Server.	This system is developing advanced applications infrastructure (G2) and interfacing with the SDS. User is FR#2/BNA/NASA management.
SCAN-LSDN	Currently an HP-UNIX based series of networked computers. This sensitivity level 3 system is used to develop and sustain CCMS applications software. Also Shuttle Connector and Analysis Network (SCAN) application is deployed on the same (LSDN) network.	Allow for X-term session connectivity to LSDN-SCAN.	Issue: address the security and sensitivity classification for connectivity from BASIS. (will BASIS be a level II system??)

System	Existing Mode	Suggested Mode	Comments
STA Passive Downlink	System uses OSR located PC and dedicated comm lines to acquire STA downlink at SLF (RF Modem). Data is then made available to Range Wx via dial-up 9600 baud phone line.	Do not port to CLCS. User is USAF Weather.	System is utilized to route STA weather information to the USAF Weather computer. It's unclear if there is a CLCS User/Customer for this information on the CLCS SDS.
KATE/LEX	Knowledge based Autonomous Test Engineer/LOX Expert System.	Allow for X-term session connectivity to this system. Allow for this processing asset (computer/server) to be connected to the BASIS.	Currently no initiative to advance this application.
Meteorological Monitoring System	External (to CCMS) weather measurements now included in the Shuttle data stream (METRO) and allowing for RTPS Displays, recording and retrieval.	This item has already been addressed by CLCS by adding its data to the consolidated data stream and building PC-GOAL displays.	USAF & NASA Safety needs to verify this satisfies their needs.
APU Neural Network Tool	Utilized in FR#2 by NASA and BNA Management to plot and assess key APU parameters. Provides Real-Time CRT Plotting and trend analysis. Currently funded by CLCS to port to SDC ALPHA Applications Server.	Potential for RPS Strip Chart (on screen) functionality. CERTIFY the data acquisition and presentation software components for use on the BASIS Work Station.	Potential for providing a major part of the RPS functionality (CRT Based Real Time Plots) at the control room console's BASIS Support Workstation.
EXODUS Deployment to DLES and PSA.	This capability adds engineering database information to the PSA and DLES projects. Most of this functionality has been ported to web based databases on the LPSWEB.	Do Nothing.	This information will be available to the BASIS/BIN users via WEB interfaces.
Add GUFI/CDS access S/W to PC-GOAL Workstations	This item is currently being investigated under the listed CERT tracking number.	The CLCS Robust Web Interface efforts to access SDC/CDS archival data satisfies this requirement. Do nothing new on this item.	BASIS/BIN users will all have this functional capability.
RI-NASA CD-ROM based wirelist/database computer.	Currently a web and FOXPro database PC implementation.	Do Nothing. The baseline BASIS/BIN workstation will be able to perform these functions.	Some of the S/W deployment is by manual CD-ROM execution. This capability on the BASIS would allow for central distribution of this data (e.g. CLCS/BASIS File server).

System	Existing Mode	Suggested Mode	Comments
S0007 CAP-145 Plot System	Only approved for use in the DRR, utilizes a PC with GUFI S/W to access CDS CAP-145 and display analysis data.	This requirement being satisfied by the BASIS/BIN and CDS/SDC upgrade. Do Nothing New.	Application involves resolving flight control test anomalies late in the countdown (MPS TVC and AERO TVE Gimbal/Ramp Tests.
4th Position Workstation	Evaluation of engineering tools workstation in the CCMS environment.	Do Nothing, the BASIS/BIN will have this functionality.	
MEC Preflight BITE Data Analysis Laptop	This item was withdrawn by the user due to lack of available assets (LAPTOP)	This capability to be implemented in the RTPS Apps.	
Lox Vibration Analyzer-Monitor	This special purpose signal analysis and display computer is utilized during CRYO operations. Currently located in 3P18. Utilizes dedicated comm/wideband circuits to advisory digital signal processing and analysis.	Re-host (e.g. ENTEk IRD) to a standard open systems OS Application Server platform. Locate server in SDC/RPS and wire both pads to this system (no physical patching). Provide CLCS/SDC API system services. Write (part of re-host) data packet logging software utilizing COTS S/W provided API. OCR users will X-Term into this system.	Currently a dedicated engineer mans this digital signal processing analysis tool during cryo operations. This system utilizes dedicated wideband circuits into analog-to-digital interfaces on a unique vendor solution platform. Only one system exists, is patched for pad A or B.

Appendix B Current Business System Interfaces

The following table documents current external business system and reference information interfaces (this list is expected to be very dynamic and grow):

System Name	Interface
Engineering and Data Management System (EDAMS)	X-Term
Integrated Work Control System/Shuttle Processing and Data Management System (IWCS/SPDMS)	Tn3270, Oracle Forms Client
Shuttle Connector Analysis Network (SCAN)	X-Term
LPS Software Development Network (LSDN)	X-Term
Kennedy Engineering Drawing System (KEDS)	Web Browser-Plug In
Shuttle Drawing System (SDS)	Web Browser-Plug In
SFOC-USA • E-mail • Intranet-WEB • Scheduling	 • USA Ground Ops LAN • Web Browser • USA Ground Ops LAN
GPSS-KICS Scheduling	Web Browser-Plug In
Shuttle Data Center (SDC)	X-Term & Web Browser
Shuttle Engineering and Computer Application System (SECAS)	Functionality being replaced by components on the USA Ground Ops LAN
ASMS ??	??
PC-GOAL	WEB Browser access (External to the CLCS Set) PC-GOAL functionality on BASIS/Support Workstations attached to the BIN.
HUMS	X-Term to HUMS Server
ILMF PTS Databases, Planning Databases & Technical Notification System	Custom Client, Workstation Execution
PDMS & PDC (Payload Data Management)	Telnet, WEB Browser

The following table lists typical Support Workstation Software & Functions.

Application or Software	**Use or Function**
NT 4.0 SP3 OS MS Office 95 Pro MS Internet Explorer 3.02 (+ Plug Ins) Adobe Acrobat Reader 3.1 Netscape 3.02 (+ Plug Ins) SMS Client MS Exchange 4.0 MS Schedule Plus Norton Antivirus Client NTP Client (D4-time) WAVE S/W Suite	Operating System & Office Environment
PC Plot, PC-DAP (232)	Plot and Data Analysis Utilities

Application or Software	Use or Function
Passport, Telnet	TN 3270 and VT340 Terminal Emulation, access to SPDMS, PDMS and other HOSTS.
Reflections-X, PC-Xware	X-Server access to X-Windows/Motif compliant remote applications
SL-GMS	Execution Engine for the SL-GMS Real Time Displays
Visio Technical	Engineering Drawing Application
WAVE S/W Suite: - SGML Editor/Viewer (Arbortext) - Document CM Application (TBD) - Drawing/Graphics Package (Coral) - Other Apps (TBD)	OMI, PR, IPR, TPS Authoring and Viewing Office Applications.
ILMF Database Access Client	O&M User Data Access
RAZOR Workstation Client	O&M and Applications Sustaining Access
ORACLE Forms	DB Client User Access (Access to SPDMS Hosts and SDC DBs)
Internet Browser Plug-Ins	Various Plug Ins including, streaming audio, streaming video, VRML, QuickTime, ODBC Connector's etc.
Net Meeting	White Board

Appendix C HCI Tracking Matrix

Function	Sub Function	C&C HCI	C&C HCI Same RSYS	Other C&C HCI	BIN	Office	Offsite
Data Display	High End Dynamic Display	SD&T	SD&T	SD&T	SD&T	SD&T	SD&T
Data Display	Light Weight	?	?	?	SD	SD	SD
Data Display	Special Application Interface	Independent	Independent	Independent	Independent	Independent	Independent
Data Display	Color Changes	SD&T	SD&T	SD,SD&T	SD,SD&T	SD,SD&T	SD,SD&T
Data Display	DEMON	SD&T	SD&T	SD	SD	SD	SD
FD Viewer	Data	SD	SD	SD	SD	SD	SD
FD Viewer	Fusion Function	SD	SD	SD	Equivalent	Equivalent	Equivalent
FD Viewer	Fusion Inputs	SD	SD	SD	Equivalent	Equivalent	Equivalent
FD Viewer	Fusion Internal Variables	SD	SD	SD	- - -	- - -	- - -
FD Viewer	Health	SD	SD	SD	Equivalent	Equivalent	Equivalent
FD Viewer	Health Reasons	SD	SD	SD	- - -	- - -	- - -
FD Viewer	Time Stamp	SD	SD	SD	Equivalent	Equivalent	Equivalent
FD Viewer	Plotting	SD	SD	SD	Equivalent	Equivalent	Equivalent
Constraints	Set Constraints	SD&T	SD&T	SD	- - -	- - -	- - -
Constraints	Read Constraint	SD&T	SD&T	SD	- - -	- - -	- - -
Constraints	Constrain Monitor	SD&T	SD&T	SD	Equivalent	Equivalent	Equivalent
System Messages	View	SD	SD	SD	Equivalent	Equivalent	Equivalent
System Messages	Filter	SD	SD	SD	Equivalent	Equivalent	Equivalent
Command	Feedback	SD&T	SD&T	SD&T	SD&T	SD&T	SD&T
Command	End Item Command Data				required	required	required
Command	System Message	Required	If requested	If requested	Equivalent	Equivalent	Equivalent
Command	Input	Independent	Independent	Independent	- - -	- - -	- - -
Command	Response	Independent	Independent	Independent	- - -	- - -	- - -
Retrieval	Near Term	Independent	Independent	Independent	Independent	Independent	Independent
Retrieval	Long term	- - -	- - -	- - -	Independent	Independent	Independent
End Item Manager	Display State	SD	SD	SD	Equivalent	Equivalent	Equivalent
End Item Manager	Debug	Independent	Independent	Independent	- - -	- - -	- - -
End Item Manager	Control	Independent	Independent	Independent	- - -	- - -	- - -
System	Health	SD&T	SD&T	SD&T	Equivalent	Equivalent	Equivalent
System	Integrity	Independent	Independent	Independent	- - -	- - -	- - -
System	Control	Independent	Independent	Independent	- - -	- - -	- - -

Function	Sub Function	C&C HCI	C&C HCI Same RSYS	Other C&C HCI	BIN	Office	Offsite
Window Layout	Cursor Movement	Independent	Independent	Independent	Independent	Independent	Independent
Window Layout	Movement	Independent	Independent	Independent	Independent	Independent	Independent
Window Layout	Re-Size	Restrict	Restrict	Restrict	Independent	Independent	Independent
Window Layout	Overlay	Restrict	Restrict	Restrict	Independent	Independent	Independent
Window Layout	Fixed Location	Required	Required	Required	Independent	Independent	Independent
Business Functions	Office Tools	- - -	- - -	- - -	Required	Required	Required
Business Functions	Access to Other System	- - -	- - -	- - -	Required	Required	Required
Business Functions	Mail	- - -	- - -	- - -	Required	Required	Required

Legend:

SD&T	Provide same display and have data track on all displays
SD	Provide same display
Equivalent	Provide an equivalent display all feature need not be present
Independent	Each display is different
Restrict	Limit function

END